Size and characteristics of the biomedical research workforce associated with U.S. National Institutes of Health extramural grants

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ABSTRACT **The U.S. National Institutes of Health (NIH) annually invests approximately $22 billion in biomedical research through its extramural grant programs. Since fiscal year (FY) 2010, all persons involved in research during the previous project year have been required to be listed on the annual grant progress report. These new data have enabled the production of the first-ever census of the NIH-funded extramural research workforce. Data were extracted from All Personnel Reports submitted for NIH grants funded in FY 2009, including position title, months of effort, academic degrees obtained, and personal identifiers. Data were de-duplicated to determine a unique person count. Person-years of effort (PYE) on NIH grants were computed. In FY 2009, NIH funded 50,885 grant projects, which created 313,049 full- and part-time positions spanning all job functions involved in biomedical research. These positions were staffed by 247,457 people at 2,604 institutions. These persons devoted 121,465 PYE to NIH grant-supported research. Research project grants each supported 6 full- or part-time positions, on average. Over 20% of positions were occupied by postdoctoral researchers and graduate and undergraduate students. These baseline data were used to project workforce estimates for FYs 2010–2014 and will serve as a foundation for future research.—Pool, L. R., Wagner, R. M., Scott, L. L., RoyChowdhury, D., Berhane, R., Wu, C., Pearson, K., Sutton, J. A., Schaffer, W. T. Size and characteristics of the biomedical research workforce associated with U.S. National Institutes of Health extramural grants. *FASEB J.* 30, 1023–1036 (2016). www.fasebj.org**

Key Words: researcher census · occupation · career stage · educational attainment · personnel age distribution

The mission of the U.S. National Institutes of Health (NIH) is to improve health and save lives, which it accomplishes in large part by investing in biomedical research through grants to universities, teaching hospitals, research centers, and other institutions across the country and around the world through the NIH extramural grant program. In fiscal year (FY) 2009, the initial year of this study, the NIH invested almost $22 billion (1)—72% of its budget—in funding for grants to extramural institutions and their investigators. The leading research universities receive hundreds of millions of dollars in funding each year, and these universities have come to rely on NIH for support of faculty and research staff salaries (2). In addition, NIH funding supports most of the biomedical research training, either directly through the Ruth L. Kirschstein Institutional National Research Service Award (NRSA) training grants and fellowships or *via* positions on research grants (3).

As the largest funder of biomedical research and training in the world, the NIH is central to discussions of the future of biomedical research and the research workforce. Many believe the biomedical research community is at a crossroads: even as scientific breakthroughs continue occur at a rapid pace, systemic flaws are threatening the sustainability of the academic research enterprise, and grant resources are stretched increasingly thin (4). It has been posited that these conditions arise from a structural disequilibrium, in which far more scientists are being trained than can eventually be supported by grant funding (5). This debate has led to a widespread interest in the size and composition of the biomedical research workforce.

In past years, NIH has routinely collected data on the principal investigators (PIs) of research grants and NRSA-funded trainees and fellows. As a result, information about these individuals is available on the NIH website and has

Abbreviations: ARRA, American Recovery and Reinvestment Act of 2009; FACP, Fellow of the American College of Physicians; FY, fiscal year; GSS, NSF-NIH Survey of Graduate Students and Postdoctorates in Science and Engineering; IMPAC II, Information for Management, Planning, Analysis, and Coordination II; MPI, multiple principal investigator; NIH, U.S. National Institutes of Health; NRSA, Ruth L. Kirschstein National Research Service Award; NSF, National

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been extensively analyzed (6). Much less is known, however, about other personnel who are vital to the research process, such as staff scientists, laboratory technicians, and non-NRSA–supported student trainees. To address this gap, NIH endeavored to use administrative data to assess the grant-associated workforce in 1993 (7) and in 2008 (8). Both assessments were based on key personnel information listed in the individual grant progress reports, and the latter evaluation found significant underreporting of research support staff in the key personnel information, including early career scientists and students.

Alternative methods to enumerate the NIH-funded workforce have been used in studies focused on documenting the economic impact of scientific research funding. Two advocacy organizations—Families USA and United for Medical Research (UMR)—have used economic modeling to estimate the number of biomedical research personnel, as well as the additional people employed indirectly through NIH funding (9, 10). The STAR METRICS (Science and Technology in America's Reinvestment–Measuring the Effect of Research on Innovation, Competitiveness and Science) program uses university administrative and personnel records to obtain project-level information about the federally funded workforce (11). Although these data can provide overall estimates of the NIH-funded workforce, and in the case of STAR METRICS, some individual-level data, they have been used primarily to measure job creation.

Lack of comprehensive data on the NIH-funded biomedical workforce has limited NIH policy discussions and recommendations. In 2012, the NIH-commissioned Biomedical Research Workforce Working Group Report made extensive use of data from National Science Foundation (NSF) surveys and the Association of American Medical Colleges (AAMC), but noted numerous data gaps (3); and, all too often, persons in the biomedical research community fill in the data gaps using anecdotal and personal observations as their information source (11, 12), which does not contribute to evidence-based policy making.

To improve the collection of personnel data, NIH modified its policies and, beginning in FY 2010, required reporting, on the annual grant progress report, all personnel who had devoted a month or more of effort in the previous fiscal year to that research project (13). The All Personnel Report allows for an annual census of the personnel associated with NIH extramural grants.

Our study was initiated to leverage the new information in the All Personnel Report, introduced in 2010, to develop a more reliable estimate of the size and nature of the extramural grant workforce. Because some individuals identified on the All Personnel Report contributed to more than 1 NIH grant, we sought to determine not only the number of positions, but also the number of unique persons filling these positions, and the total amount of effort devoted by these persons associated with NIH grants funded in FY 2009. We used the age and educational attainment recorded on the All Personnel Report to provide insight into career trajectories. In addition, we linked these data to the NSF Survey of Earned Doctorates (SED), so as to further characterize the pool of early career scientists.

Finally, we used the FY 2009 baseline data to project the total number of positions, persons, and years of effort associated with the NIH grants awarded in FYs 2010-2014, to assess any workforce changes that may be coincident with shifts in funding and project activities supported by NIH in the latter years. These projections are of particular interest as a result of slowdowns in federal funding because of the recession of December 2007 through June 2009 (14) and the budget sequestration of 2013, which have led to a decline in constant dollars in NIH funding since FY 2009.

MATERIALS AND METHODS

Personnel estimates were based solely on NIH extramural grants. All grant mechanisms were included (*e.g.*, research project, center, training, and fellowships). NIH research and development contracts and associated extramural personnel were excluded. Most NIH grants are awarded competitively in the first year and funded incrementally in each subsequent noncompeting year of the grant period, if progress is satisfactory. Research grants can be made for up to 5 years, and for each noncompeting year, the PI is required to file a progress report. The All Personnel Report is a component of this progress report, and the PI, as well as all other persons devoting a month or more of effort to the grant during the previous fiscal year, are required to be listed, regardless of their role on the project or whether the grant funded their salary. The All Personnel Report captures positions associated with direct costs of grants, but excludes positions associated with indirect costs, such as facilities and administrative costs of grants. This study used FY 2010 progress reports to enumerate the grant personnel associated with FY 2009 funding.

To begin, a listing of all grants supported by NIH in FY 2009 was created with the goal of obtaining a progress report for each project. Grants funded through the American Recovery and Reinvestment Act of 2009 (ARRA) were excluded from this analysis. ARRA was a one-time stimulus of U.S. government funding, tax cuts, and benefits made in response to an economic crisis and was designed to spur economic activity and invest in long-term growth (15). Under ARRA, NIH received an additional $10.4 billion beyond its usual FY 2009 and 2010 Congressional appropriations.

Because of supplemental awards, it is possible for multiple grants to be associated with a given project in a single FY. Only one progress report is submitted per project annually; there were 50,885 non-ARRA grant projects funded in FY 2009 from 53,453 non-ARRA grant awards, including supplements. With the unique project identification number, the NIH database of information on extramural applications and awards known as Information for Management, Planning, Analysis, and Coordination II (IMPAC II) was used to obtain associated personnel information. The available personnel information was downloaded directly from IMPAC II for all grant PIs, for the electronically submitted progress reports (51% of total projects), and for the training and fellowship grants (10% of projects). Progress reports were submitted on paper for 11% of projects. For paper progress reports, the All Personnel Reports were scanned as a normal part of the administrative process, and those images were available in IMPAC II but required subsequent extraction and parsing into individual data fields to enable further analysis. The information on the scanned image of the progress report was

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Science Foundation; OCR, optical character recognition; PI, principal investigator; PYE, person-years of effort; RIMS, Regional Input-Output Modeling System; RPG, research project grant; SED, NSF Survey of Earned Doctorates; SBIR/STTR, Small Business Innovation Research/Small Business Technology Transfer; SSN, Social Security number; UMR, United for Medical Research extracted from the All Personnel Forms *via* optical character recognition (OCR) software. The software was able to automatically extract all but 52 of the All Personnel Reports, which were manually entered into a database for analysis.

Data from all sources were combined, cleaned, and coded. The All Personnel Report collects the following elements for each person listed on the report:

- Name;
- Commons profile ID (a unique username for institutional signing officials, PIs, trainees, and postdocs who are required to register with the eRA (Electronic Research Administration) Commons, an online interface for accessing and sharing administrative information relating to NIH grants);
- Last 4 digits of the Social Security number (SSN);
- Month and year of birth;
- Educational degree(s) attained;
- Occupational position title on the grant (*e.g.,* PI);
- A funding code to indicate whether the position was funded through NIH supplemental funding; and
- Months of effort-time spent on the grant, divided into calendar year, summer, and academic year variables.

Nonspecified position records (*e.g.,* To Be Hired) were removed from the dataset. Position records with an ARRA-related supplemental funding code ($N = 2226$) were also excluded. The enumeration of the position type, effort-time, degree information, and age distribution was used to characterize the workforce.

A standard set of 11 occupational position types was provided in the initial All Personnel Report guidance (see *http://grants.nih.gov/grants/guide/notice-files/NOT-OD-12-152.html* and ref. 16). PIs were encouraged to code their project personnel according to this taxonomy. For the electronically submitted information, investigators were given a drop-down menu, from which they could pick one of the standard classifications or choose an "other" category, for which they were then asked to specify the position title. Seventy-one percent of the electronically reported personnel were assigned a standard position classification by the PI. Personnel reported in "other" positions were manually classified. Because the paper-based forms allowed for a free-text field, many of the position titles required manual categorization. Using the existing positions and additional position categories that appeared frequently in the "other" category, a standard taxonomy of 20 position types was created and then vetted and finalized by the entire study team. Two staff members independently coded all titles to this taxonomy, with an additional staff member serving as arbiter for any titles classified differently by the two coders. Over 23,400 unique free-text position titles were processed. To perform aggregated position analysis, the 20 position types were grouped into 4 broad categories: Senior Researcher, Research Support, Training and Related, and Other/Unknown. Individuals listed as Research Assistants or Coordinators without further specification of whether they were students or postdoctoral researchers, were classified to the Research Support category. Individuals supported by institutional career (K) and institutional training (T) awards were classified under the Training and Related category, whereas PIs for the institutional and individual career awards and institutional training awards were classified as PIs under the Senior Researcher category. Although individuals receiving fellowship (F) grants were PIs of their awards, they were classified to the Training and Related, rather than the PI category. The Other/Unknown category was excluded from position specific analyses.

Beginning with research grant applications submitted in February 2007, the NIH allowed applicants and their institutions to identify multiple principal investigators (MPIs), to permit more than 1 PI to share the authority and responsibility for leading and directing the project, intellectually and logistically (17). In this analysis, persons designated as MPIs were categorized into the PI position category. Co-investigators are senior or key personnel involved in the scientific development or execution of a project, but are not PIs or MPIs.

Many biomedical research staff are affiliated with multiple grants, providing several months of effort-time to each project. In addition to counting all positions on all projects, the number of unique persons that devote effort to NIH-funded projects was of interest. To achieve this aim, a de-duplication algorithm that used the personal and grant information elements to determine duplicates was constructed. The personally identifying information collected on the All Personnel Report—name, last 4 digits of the SSN, birth month and year, and NIH Commons profile ID—was used in conjunction with information related to the grant itself—the name and location (city and state) of the institution receiving the grant—to identify individuals affiliated with more than 1 grant within the enumeration dataset.

Degree information was collected to ascertain the level of educational attainment for persons engaged in biomedical research at different career stages. This free-text field netted 989 different degree and professional certification acronyms, which were classified. The degree was classified to the broad level of educational attainment, corresponding to the highest level of education achieved (*e.g.,* those who reported both bachelor's and master's degrees were reported in the master's category, and those who reported master's and doctorate degrees were reported in the doctorate category). For those who had received a doctorate (>50% of those who reported degree information), 5 mutually exclusive doctorate categories were created: Doctor of Medicine (M.D.) Only, Doctor of Philosophy (Ph.D.), M.D./Ph.D., Clinical Doctorate, and Other Doctorate. The M.D. category included persons who reported equivalent degrees; likewise, the Ph.D. category included those with equivalent degrees. The Clinical Doctorate category included other doctoral-level health professionals, such as those holding degrees in dentistry, veterinary medicine, or optometry. The Other Doctorate category included nonclinical professional doctorates, such as law or public administration. Many reported professional certification acronyms in lieu of, or in addition to, their degree information. If the certification required a minimum specified level of education, it was codified to that degree level [*e.g.,* using the FACP designation (the acronym for Fellow of the American College of Physicians) requires that one have an M.D. or equivalent degree]. Degrees offered only at non-U.S. institutions were codified to the equivalent U.S. degree.

Approximately 92% of the extracted records had associated effort-time, reported as the number of months that the particular individual was involved with the project. Most reported in the calendar year method; only a small portion of records (7%) used the alternative summer and academic year reporting approach. Using the records with associated effort-time, the calendar year, summer, and academic year fields were summed to produce an annual effort-time calculation. The OCR technology incorrectly processed some effort-time reported on the paper forms, thus rendering a small percentage of the effort-time extraction unusable. For all records for which these data were unavailable, the median effort-time was imputed for the particular position category.

Personnel information was entirely missing for 28% of FY 2009 grant projects. This is because, in the initial implementation of the All Personnel Report, PIs were not required to submit an All Personnel Report with the final grant report. In addition, All Personnel Reports were not required for multiyear-funded grants that receive funding for the entire project period in the first year; the latter are required to submit final grant reports but not annual progress reports.

To estimate the full number and effort of personnel working on NIH grant projects in FY 2009, data were imputed for the projects for which an All Personnel Report was not available or required, using the existing grant records with available personnel data. A median number of position types per dollar was calculated, by using totals of direct-cost dollars and occupational position types by activity code. For each project in the imputation file, the direct cost amount was multiplied by the median position type per dollar within the associated activity code, yielding an estimate of the number of positions by occupational position type. An imputation file was created with the project number, position type, and number of roles associated with the position, to the nearest tenth. Then, using the position:person ratio by occupational position type from the existing data records, the number of persons was added to the position listing. Finally, the position: effort-time ratio by occupational position type was added, based on the existing data records. Data imputation added an additional 65,138 positions, 58,196 people, and 264,019 mo of effort-time to the calculation totals. Because information on PIs was available in IMPAC II for 100% of the projects, no PI records were added through imputation. In addition, IMPAC II also contains detailed information on undergraduates, graduate students, and postdoctoral researchers associated with training and fellowship grants (Ts and Fs), and therefore no records were added through imputation for these grants.

Using the cleaned and combined data, descriptive statistical analyses on positions (the full list of personnel records including the imputed positions), persons (the de-duplicated list of personnel records including the imputed persons), and person-years of effort (PYE) for FY 2009 were produced. One PYE was defined as 12 mo of effort by 1 or more persons (*e.g.,* 2 persons devoting full-time effort for 6 months equals 1 PYE). To compute PYE, the total effort-months of time were summed across the personnel records and imputed records and divided by 12. All data preparation and analysis was performed with SAS software 9.2 (SAS Institute, Cary, NC, USA).

In the analyses broken down by occupational position, persons who were reported in more than 1 role type were included in each of those role type categories. For example, if a 35-yr-old person was reported as a postdoctoral researcher on one grant and staff scientist on another grant, she or he would be included in the age distributions for both position types.

Supplemental Table S1 provides a breakdown of the average number of positions per grant and the average number of PYE per grant for each activity code in FY 2009. By multiplying the FY 2009 averages by the number of grants in each activity code in each FY 2010 through 2014, we estimated the total workforce positions and total PYE for those years. Furthermore, we used the overall ratio of positions:persons to estimate the number of unique persons in these later FYs (Table 3). New activity codes not used in FY 2009 were assigned values from other similar activity codes that were used in FY 2009.

The NIH Office of Human Subjects Research Protections reviewed this work and determined that it was not human subjects research and therefore did not need review by an Institutional Review Board.

RESULTS AND DISCUSSION

Workforce totals and projections

The primary objective of the first set of analyses was to determine the overall number of full- and part-time positions, unique persons, and distinct PYE associated with NIH-funded grant projects in FY 2009, as well as counts by occupation type. We used overall position, person, and PYE counts to project the workforce for NIH-funded grant projects from FY 2010 to FY 2014.

Total workforce positions

There were 313,049 full- and part-time positions on NIH-funded grant projects in FY 2009. This estimate is about 10% lower than the figure reported by Families USA in 2008, which estimated that NIH funding created 350,894 jobs in FY 2007 (9). However, this difference was unsurprising because the Families USA estimate used an approach to economic modeling known as the Regional Input-Output Modeling System (RIMS) II multiplier to determine its employment estimates, and these estimates included full- and part-time, primary and secondary jobs created from both NIH grant and contract funding. In the Families USA study, primary jobs were those arising from NIH extramural funding to institutions, including dollars to support specific research projects and facilities and administrative costs. Examples of such jobs include PIs, laboratory technicians, and university administrators. These primary personnel also spent money on other goods and services in the economy, contributing to the salaries of other employees, who themselves spent money. Economists call these successive rounds of expenditures "the multiplier effect." Multipliers can be quantified and were used in the Families USA study to estimate the number of secondary jobs from the initial NIH funding to institutions.

In contrast, the current analysis addressed only the positions associated with the direct cost portions of NIH grant awards, excluding positions linked to facilities and administrative costs of these grants. Also excluded from the current analysis were positions associated with contract funding, which represented an additional 10% of the NIH budget.

An additional study using the RIMS II multiplier was conducted by UMR, which found that FY 2010 NIH funding, excluding ARRA dollars, supported 403,389 jobs (8). The UMR estimate was almost 29% higher than that found in the current analysis. Like the estimate from Families USA study, the higher UMR figure was partially because of the inclusion of primary and secondary jobs created from both NIH grant and contract total funding to institutions (including direct costs and facilities and administrative costs). However, the UMR 2010 jobs figure was 15% higher than the Families USA 2007. The higher UMR job estimate likely resulted from the study having applied a national multiplier to capture economic activity *between* states, which the authors estimated to represent ~16% of national activity, as well as state multipliers to estimate economic activity *within* states. In contrast, the Families USA study used only state multipliers.

Whereas the RIMS estimates are useful for understanding the broader labor market impact of NIH grant and contract funding, our position total provides a census of personnel contributing directly to research supported by NIH grants.

Workforce position distribution

Figure 1 shows the total number of personnel by position type. This figure represents the total number of full- and part-time positions associated with all FY 2009 NIH-funded grant projects. Because some individuals devoted effort to

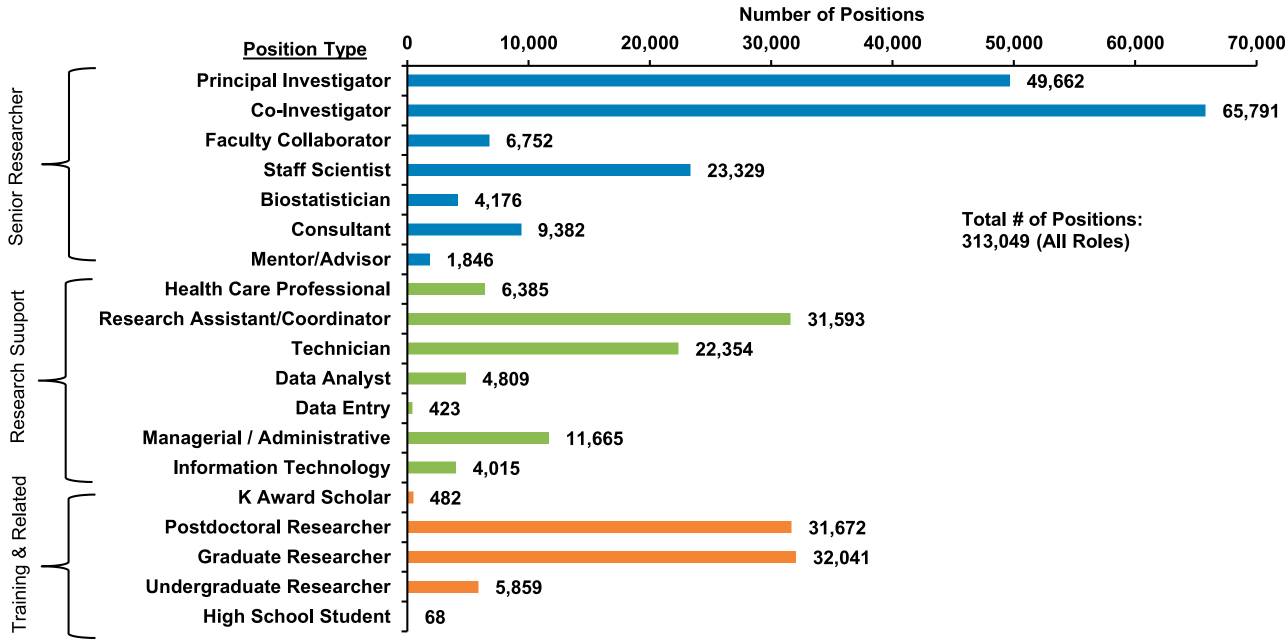

Figure 1. Number of FY 2009 extramural grant positions by position type. PI position type includes MPIs officially indicated on an NIH Grant Application. Excludes positions funded through the ARRA.

more than 1 grant project and could occupy different occupational roles on projects, persons were counted in as many positions as they were reported to hold in FY 2009. The most frequently reported roles were, in descending order, Co-investigator, PI, Graduate Researcher, Postdoctoral Researcher, and Research Assistant/Coordinator. Research Support roles comprised 26.0% of all positions reported, highlighting the importance of staff, such as technicians, data analysts, and administrators, in the success of research projects.

In FY 2009, the average number of full- and part-time positions per project was 6.2. However, this average varied among the different grant types (**Table 1**), as grant mechanisms reflect different types of research and related activities, such as research training and career development. The direct cost funding of an award correlated only moderately with the number of positions ($r = 0.51$), perhaps reflecting variations in costs associated with different types of positions.

The average frequency of the type of position also varied across mechanisms. **Figure 2** shows the average number of positions for selected position types by project mechanism. In particular, many center grants reported a high number of Co-investigators, likely representing the multiple subproject directors leading research projects and "cores" within centers. Most of NIH research grants were awarded to higher educational institutions (18). Educational institutions have ready access and commitment to the workforce in training: postdoctoral, graduate, and undergraduate researchers. In contrast, Small Business Innovation Research and Small Business Technology Transfer (SBIR/STTR) program awards are made to small businesses, which rely more heavily on staff scientists and consultants.

TABLE 1. *FY 2009 average direct cost and number of positions per project, by grant mechanism*

Grant mechanism	Total projects (n)	Average direct cost (FY 2009, U.S.$)	Average positions per project (n)
Research center grant	1,382	1,374,869	26.1
Research project grants	35,767	299,832	6.0
R01[a]	26,631	259,562	5.4
Small business research grants (SBIR/STTR)	1,802	257,606	4.4
Career development awards (K)	4,169	153,658	2.1
Fellowships (F)	2,993	40,506	1.0
Training (T)	2,216	300,295	7.8
Other awards[b]	2,556	479,185	9.4
All mechanisms	50,885	315,689	6.2

Both full- and part-time positions are included. Excludes projects and positions funded through the ARRA. [a]R01s are a subset of Research Project Grants. [b]Includes grant codes C06, D43, D71, G08, G11, G13, G20, PN2, R13, R18, R24, R25, R90, S06, S10, S11, S21, S22, SC1, SC2, SC3, U10, U13, U24, U2R, U45, U56, UL1, and UH1.

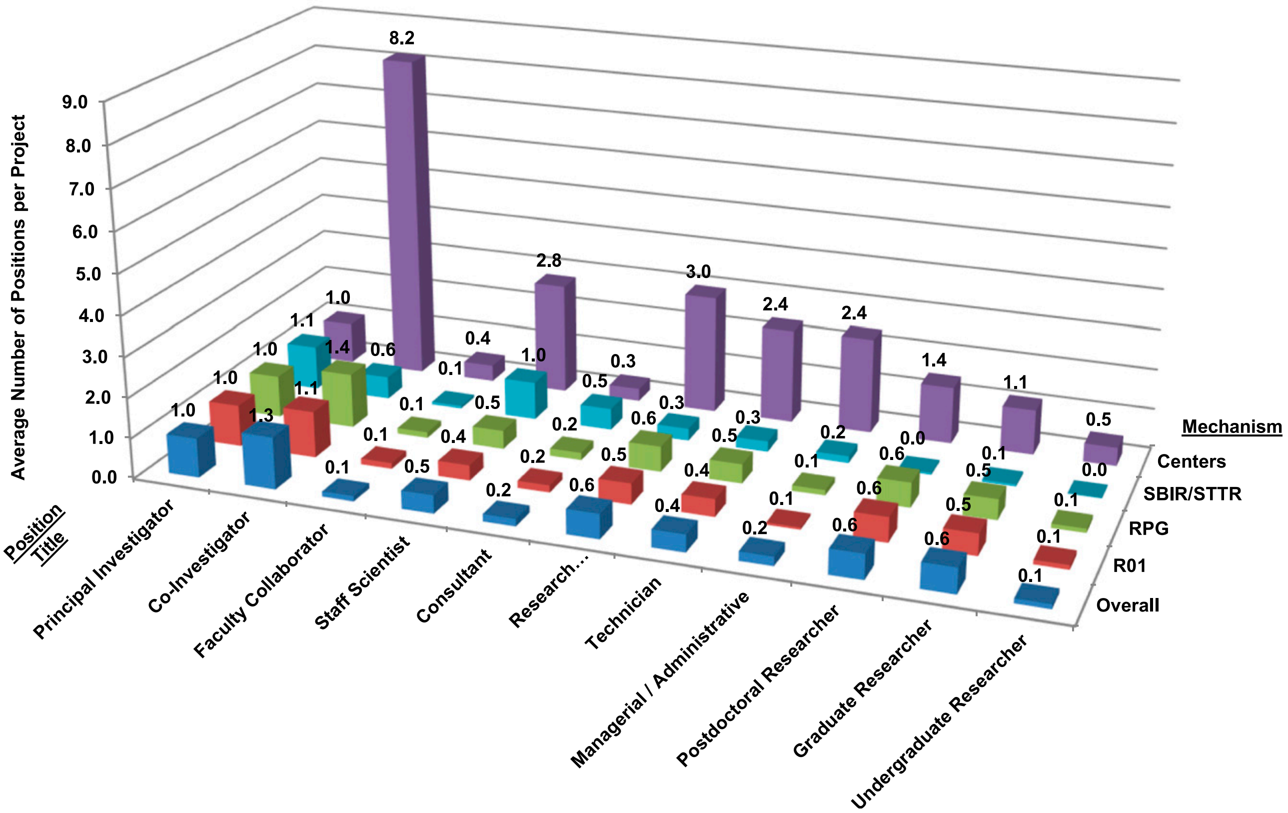

Figure 2. FY 2009 frequency of selected positions by position type and grant mechanism. PI position type includes MPIs officially indicated on an NIH Grant Application. Excludes positions funded through the ARRA.

Persons

There were 247,457 unique individuals filling positions associated with NIH-funded projects in FY 2009. This number significantly exceeds the estimate by McGarvey *et al.* (8) of 156,000 individuals associated with FY 2007 NIH grants. However, the latter study used a different reporting form based on the previous NIH policy—the Key Personnel Form—and the researchers found that many respondents reported only the PI and concluded that substantial underreporting was likely. Because the All Personnel Form contains specific instructions to list all personnel involved with the research grant, the current study's estimate of unique individuals is considered a more accurate representation of the number of people staffing positions on NIH grants.

Relationship of persons to positions

Using the de-duplication algorithm, it was possible to determine the number of unique persons reported in various full- and part-time positions. About 19% of the people working on NIH projects served in positions on 2 or more grants in FY 2009, resulting in, on average, each person working on NIH-funded projects filling 1.3 positions. Senior Researchers, particularly PIs and Co-investigators, were more likely to fill multiple positions (**Table 2**), and the most popular combinations of position types for a single person to fill were variations of the Senior Researcher types and Research Training and Related roles.

PYE

In FY 2009, 1,457,582 person-months, equivalent to 121,465 PYE, were devoted by individuals associated with NIH grants. The most recent prior assessment of PYE associated with NIH extramural funding was conducted in 1993, but was restricted to only R01 and P01 grants. The latter study reported 55,480 PYE in FY 1990 with an average of 3.3 PYE per grant (7). The present study found 59,793 PYE associated with R01 and P01 grants with an average of 2.2 PYE per grant. However, the 1993 study oversampled P01s which tend to have more associated positions (in FY 2009, P01s had an average of 8.7 PYE, whereas R01s had an average of 2.0 PYE). This oversampling may have resulted in an inflated estimate of the average number of PYE in 1990.

In the current study, for FY 2009, the overall average number of PYE per grant across all grant mechanisms was 2.4. The overall average number of months of effort devoted to a project by each project participant was ~4.7. In general, those in Senior Researcher positions devoted fewer months of effort on a project: an average of 3.4 mo for PIs and 1.7 mo for Co-investigators. Among those in Senior Researcher roles, staff scientists logged the most months of effort per project, an average of 5.6 mo (**Fig. 3**). Those in Research Support, and Training and Related positions dedicated more months of effort to a project: an average of 6.0 mo for Research Assistant/Coordinators, 6.1 mo for Technicians, 7.8 mo Graduate Researchers, and 8.4 mo for Postdoctoral Researchers. Although Postdoctoral and Graduate trainees often provide 12 mo of support to

TABLE 2. *FY 2009 ratio of project positions to unique individuals, by position*

Aggregate position level	Position title	Unique persons (*n*)	Ratio of positions to persons
Senior researcher	PI[a]	34,529	1.44
	Co-investigator	49,486	1.33
	Faculty Collaborator	6,445	1.05
	Staff Scientist	21,414	1.09
	Biostatistician	3,419	1.22
	Consultant	9,083	1.03
	Mentor/Advisor	1,773	1.04
Research support	Health Care Professional	6,090	1.05
	Research Assistant/Coordinator	29,214	1.08
	Technician	20,289	1.10
	Data Analyst	4,421	1.09
	Data entry	404	1.05
	Managerial/administrative	10,834	1.08
	Information technology	3,456	1.16
Research training and support	K award scholar	478	1.01
	Postdoctoral researcher	29,702	1.07
	Graduate researcher	31,487	1.02
	Undergraduate researcher	5,788	1.01
	High school student	68	1.00
All positions[b]		247,457	1.27

Both full- and part-time positions are included. Excludes projects and positions funded through the ARRA. [a]Includes MPIs officially indicated on an NIH Grant Application. [b]People who reported multiple position categories were counted once in each position, but were de-duplicated in the All positions count. Therefore, the sum of persons across positions does not equal the total number of unique persons.

research, many transition in and out of these roles within a given fiscal year, contributing to the slightly lower estimates of months of effort. In addition, many of these individuals provide support to multiple projects within a given year, and thus devote less than 12 mo of effort to a single project.

Figure 4 shows the total number of PYE by position type. The position types with the highest levels of associated PYE were, in descending order, Postdoctoral Researcher, Graduate Researcher, Research Assistant/Coordinator, and PI.

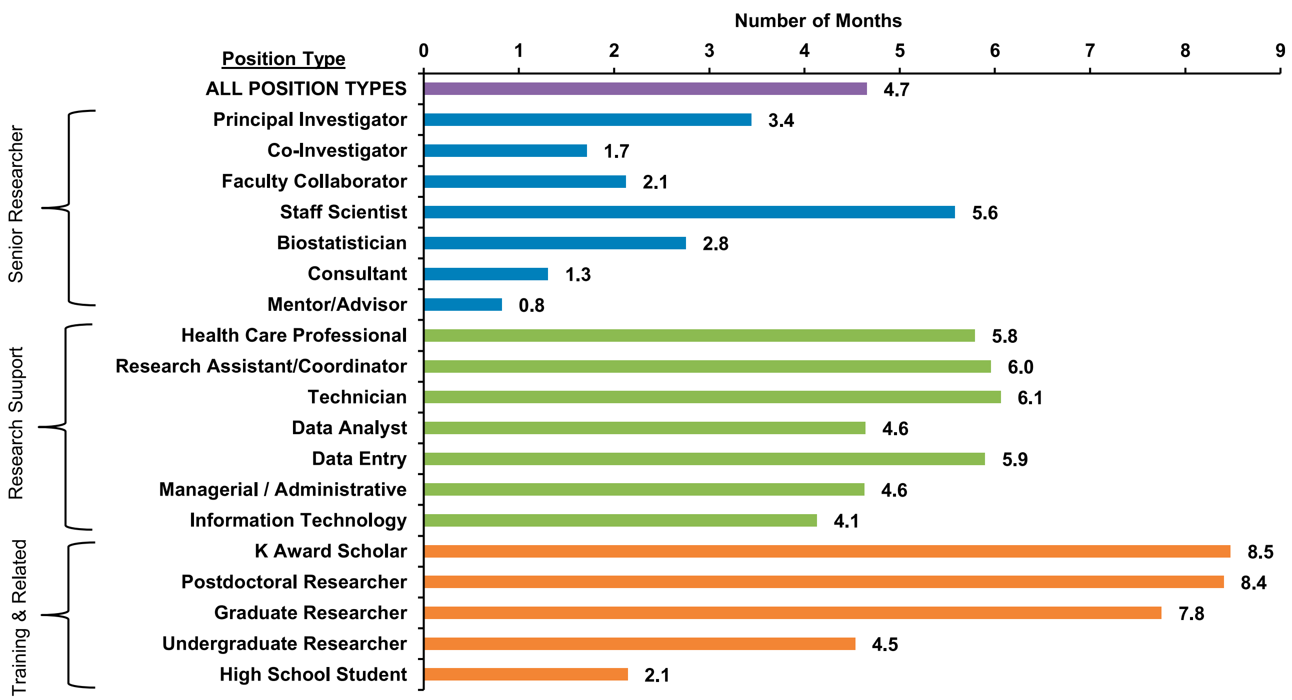

Figure 3. FY 2009 average number of months of effort per project, by position type. PI position type includes MPIs officially indicated on an NIH Grant Application. Excludes positions funded through the American Recovery and Reinvestment Act of 2009 (ARRA).

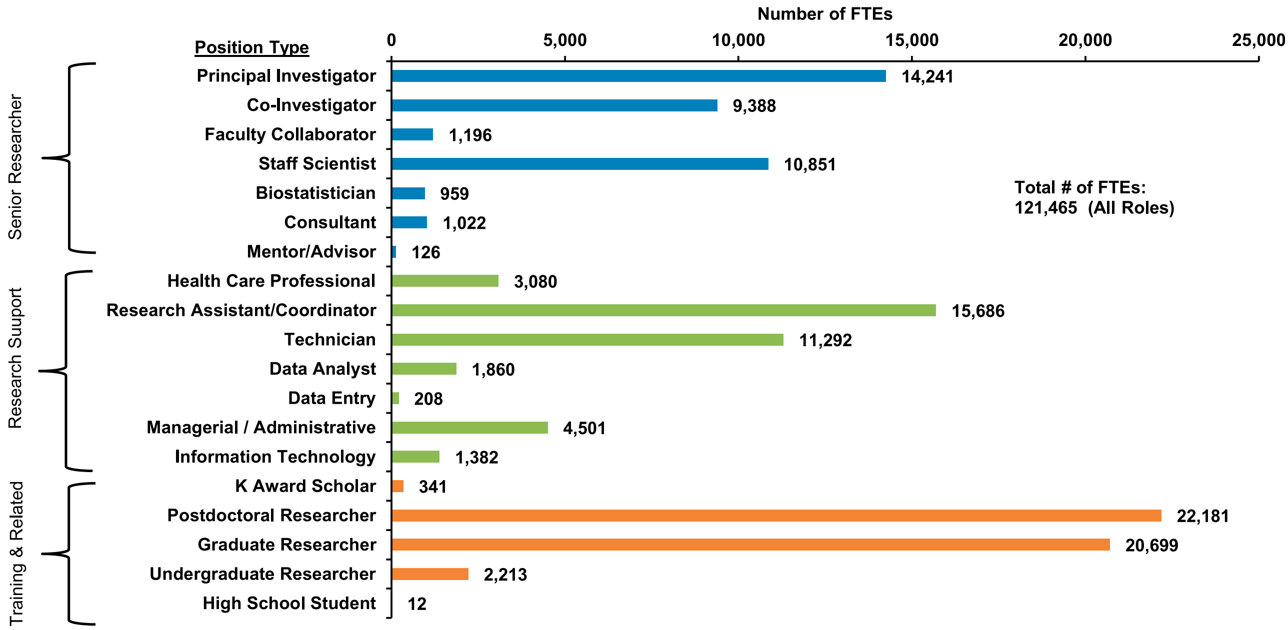

Figure 4. FY 2009 PYE, by position type. PI position type includes MPIs officially indicated on an NIH Grant Application. Excludes positions funded through the ARRA.

These data suggest that in FY 2009, PIs devoted, on average, 4.90 mo of effort to NIH grants per year [3.4 mo/project multiplied by 1.44 positions (nearly equivalent to projects)/PI]. If one assumes all of this effort was paid from NIH grants, then PIs received nearly half of their annual salary support from NIH funds. This estimate may represent an upper bound of NIH PI salary support because the All Personnel Report describes uncompensated and compensated effort. Yet, this figure could underestimate total extramural support to PIs, as it did not include PI effort associated with other roles (*e.g.,* as Co-investigators), with contracts (which lack an All Personnel Report), and from extramural awards from other agencies, information not available to the authors.

Summary of positions, persons, and person-years of effort and future workforce projections

Comparing the number of positions, persons, and PYE allows for a more nuanced view of the distribution of project-related effort and the full-time positions associated with NIH funding in FY 2009. When comparing total positions to total persons, a Senior Researcher was more likely to be contributing to 2 or more grants in FY 2009 (**Fig. 5**). However, Senior Researchers spent fewer months on a specific project, so that those in the Research Support, and Training and Related roles dedicated more PYE to research than did Senior Researchers.

The estimated workforce positions, associated persons, and the total PYE for FY 2009 and the projections for FYs 2010–2014 are listed in **Table 3**. To provide context, the number of projects funded in each year, FYs 2009–2014, and their respective total direct costs in constant 2009 dollars are also shown. Despite a 6.2% decline in total NIH grant projects and a 6.5% reduction in total direct costs associated with those grant projects between FY 2009 and FY 2014, the estimated total number of workforce positions, persons, and PYE remained relatively stable over this period (Table 3). This consistency was largely because the distribution of grants by activity codes remained similar to that in FY 2009. The slight peak in FY2012 workforce estimates was to the result of a large increase in the number of UM1 activity code grants, associated with very large, typically multimillion dollar awards. The subsequent minor declines reflected fewer dollars available for grants in FYs 2013 and 2014.

These annual projections are useful, because NIH is unlikely to repeat this study, which required significant manual effort and time, until all of the detailed data needed to enumerate and characterize NIH-associated extramural personnel are captured electronically in structured fields necessary for quantitative analysis. Many data collection enhancements are under way but are not expected to be completed for several years. The accuracy of these post-FY 2009 annual workforce projections will depend, in part, on the stability of the average values per grant by activity code over time, but because different activity codes reflect distinct types of projects and support, it is expected that their respective averages will remain stable for some time. The accuracy of these estimates also relies on the relative stability in the distribution of NIH grants by activity; as new grant activities are introduced, their staffing patterns are estimated, based on their similarity to existing grant activities.

Workforce demographics

Using the limited demographic information available from the All Personnel Report, we analyzed the educational attainment and age of the NIH-funded biomedical workforce by position type, to gain further insight into career trajectories, especially for positions for which NIH does not routinely collect or report information (12).

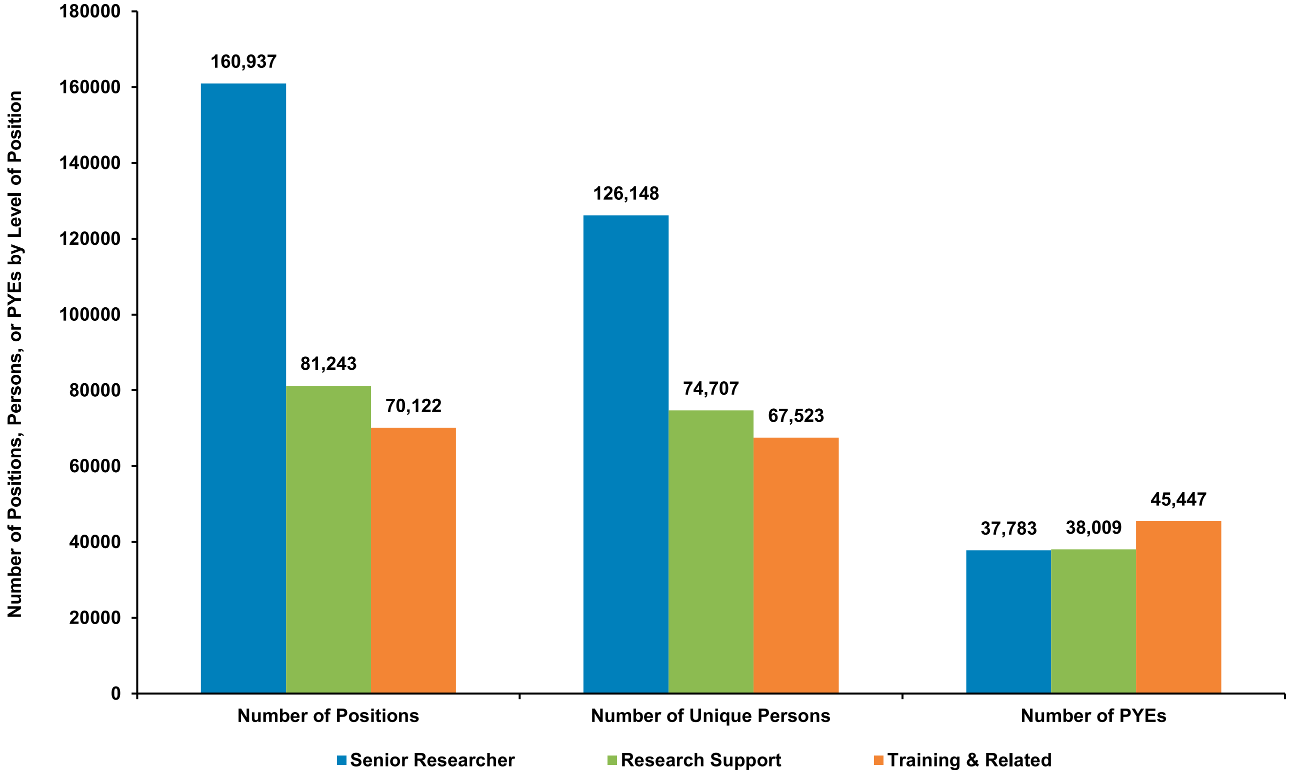

Figure 5. FY 2009 comparison of positions, persons, and PYE by aggregated level of position. Excludes positions funded through the ARRA.

Educational attainment

Of persons reporting degree information, most reported having a doctorate of some type, and over half (53%) reported having a Ph.D. as their highest degree attained. However, the frequency of degree type varied by position, as did the percentage of persons reporting. Fewer persons reported degree information in the Research Support project positions. **Figure 6** shows the distribution of educational attainment for those persons who reported degree information. Because graduate researchers, undergraduate researchers, and high school students were still working toward a degree, they were not included in the educational attainment analysis.

Senior Researcher roles such as PI, Co-investigator, Faculty Collaborator, and Mentor/Advisor were staffed almost exclusively by a mixture of persons with a professional or research doctorate. Among the most senior roles, Ph.D.s and M.D./Ph.D.s were most highly represented in the PI category, whereas those with M.D.s only

TABLE 3. *Estimated and projected positions, persons, and PYE for fiscal years 2009–2014*[a]

	Estimated	Projected				
Metric	FY 2009	FY 2010	FY 2011	FY 2012	FY 2013	FY 2014
Total projects	50,885	50,739	50,260	49,912	48,276	47,728
Total direct costs (in billions U.S.$)[b]	16.06	16.29	16.01	15.76	14.60	15.01
Total positions, *n* (95% CI)	313,049	313,172 (311,678–314,439)	312,699 (311,063–314,112)	317,984 (316,082–319,667)	314,846 (312,646–316,836)	312,584 (310,342–314,622)
Total persons, *n* (95% CI)	247,457	247,554 (246,373–248,556)	247,180 (245,887–248,297)	251,358 (249,855–252,688)	248,878 (247,138–250,451)	247,089 (245,317–248,701)
Total PYE, *n* (95% CI)	121,465	121,742 (121,032–122,343)	121,400 (120,637–122,050)	123,593 (122,722–124,353)	122,730 (121,741–123,612)	121,755 (120,760–122,644)

[a]Total number of projects and associated direct costs for FYs 2009–2014 from NIH administrative data. Total positions and PYE projections for FYs 2010–2014 were calculated on the basis of the FY 2009 All Personnel Report estimates of the mean and SE of the number of positions and PYE associated with a grant for a given activity code. For activity codes not used in FY 2009, a similar activity code, as determined by NIH staff, was used as a substitute. Total persons estimations for FYs 2010–2014 were calculated according to the person:position ratio in FY 2009, applied to the position totals for FYs 2010–2014. [b]All years adjusted to 2009 dollars by using the Biomedical Research and Development Price Index (BRDPI) (Source: Biomedical Research and Development Price Index, Updated 1-7-2014, see *http://officeofbudget.od.nih.gov/gbiPriceIndexes.html*). Excludes projects and positions funded through the ARRA.

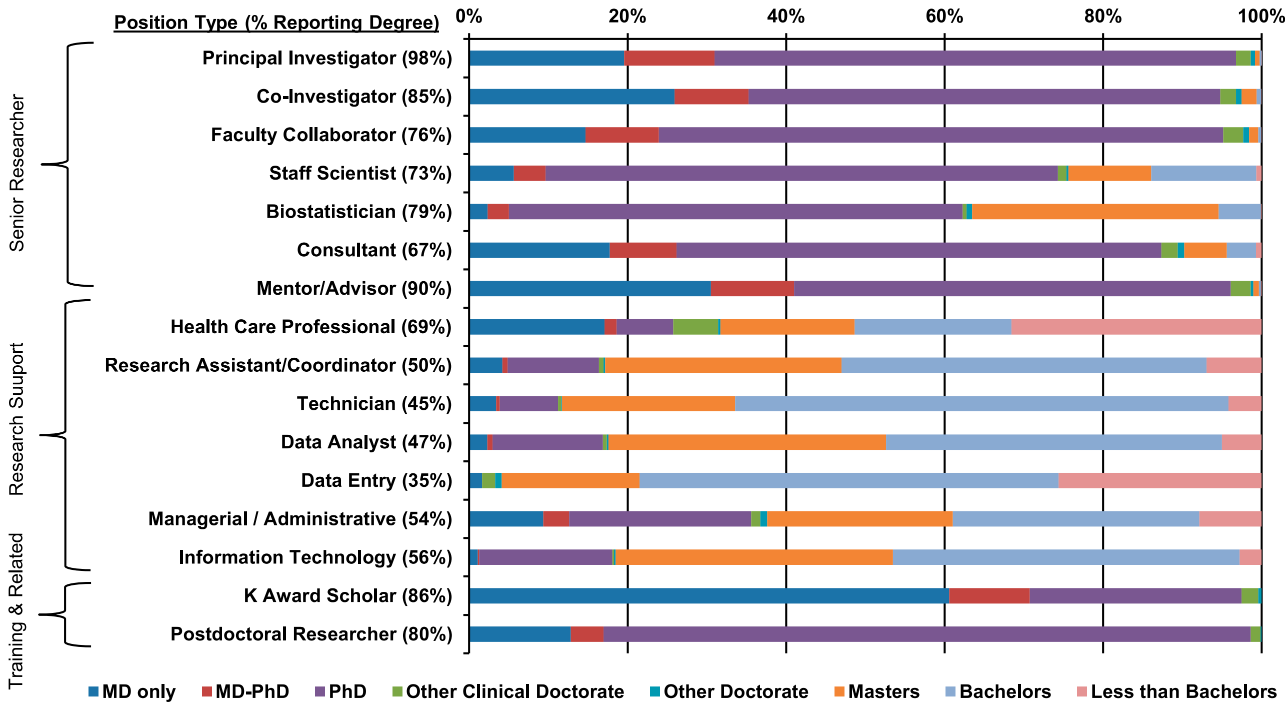

Figure 6. FY 2009 distribution of educational attainment of persons by position type. PI position type includes MPIs officially indicated on an NIH Grant Application. Other Clinical Doctorate excludes M.D. and equivalent degrees and includes D.V.M., Pharm.D., and other patient care degrees. Excludes positions funded through the ARRA.

were more likely to be in the Co-investigator role. However, even though those possessing the M.D. degree alone were more likely to be Co-investigators, the majority in this category (69%) had Ph.D.s or M.D./Ph.D.s, among those reporting their degrees. An even higher proportion of PIs (77%) indicated having a Ph.D. or M.D./Ph.D.

Other Senior Researcher roles, such as Staff Scientist, Biostatistician, and Consultant, were heavily staffed by doctorate holders but included some persons with master's- or bachelor's-level education. The Research Support roles, such as Research Assistant/Coordinator, Technician, and Data Analyst, were mostly staffed by those with a master's or bachelor's degree as the highest level attained. The Health Care Professional category was heterogeneous in educational attainment because of the inclusion of study physicians (with an M.D. or equivalent) and study nurses (with a mixture of doctoral, master's, bachelor's, and associate's levels of education), as well as individuals with other patient care backgrounds. Because the Managerial/Administrative position represented a diverse category of nonscientific grant staff, it included a mixture of doctorate holders (*e.g.,* chief executive officers, department chairs) as well as master's and bachelor's degree holders (*e.g.,* payroll administrators and staff assistants). For those who reported a master's degree as highest level of attainment, 61% reported having a Master of Science, 15% reported having a Master of Arts, and 9% reported having a Master of Public Health.

Age of personnel

Figure 7 shows the distribution of ages among the different position types. The median age for both PI and Coinvestigator was 48 yr.

Among Senior Researcher positions, the median age was similar, although slightly higher for Mentor/Advisors (53 yr) and slightly lower for those in Staff Scientist (39 yr) and Biostatistician (41 yr) roles. Among the Research Support positions, the median age was, as expected, lower than those associated with the senior positions. However, the larger interquartile ranges for these positions indicate that although many people serve in these positions early in their career, there was also a significant number of older persons who served in these roles. Training and Related positions are pegged to educational or early career experiences, and thus the median age was lower and the interquartile range tighter for these position types.

Workforce training and role of the NRSA program

As part of its mission, NIH plays a significant role in training the biomedical research workforce. This study found, in FY 2009, that NIH supported 29,702 postdoctoral researchers as well as 31,487 graduate student and 5,788 undergraduate researchers from all grant mechanisms (**Table 4**).

The figure for NIH-supported graduate students exceeds that reported by the National Science Foundation (NSF) in the results of the NSF-NIH Survey of Graduate Students and Postdoctorates in Science and Engineering (GSS), an annual survey of academic institutions in the United States that grant research-based master's degrees or doctorates in science, engineering, or selected health fields. In 2009, the GSS reported 16% fewer graduate students supported by NIH funding (N = 26,506) than found in this study (N = 31,487). About 26% of the graduate students in science and engineering fields reported in the GSS as receiving

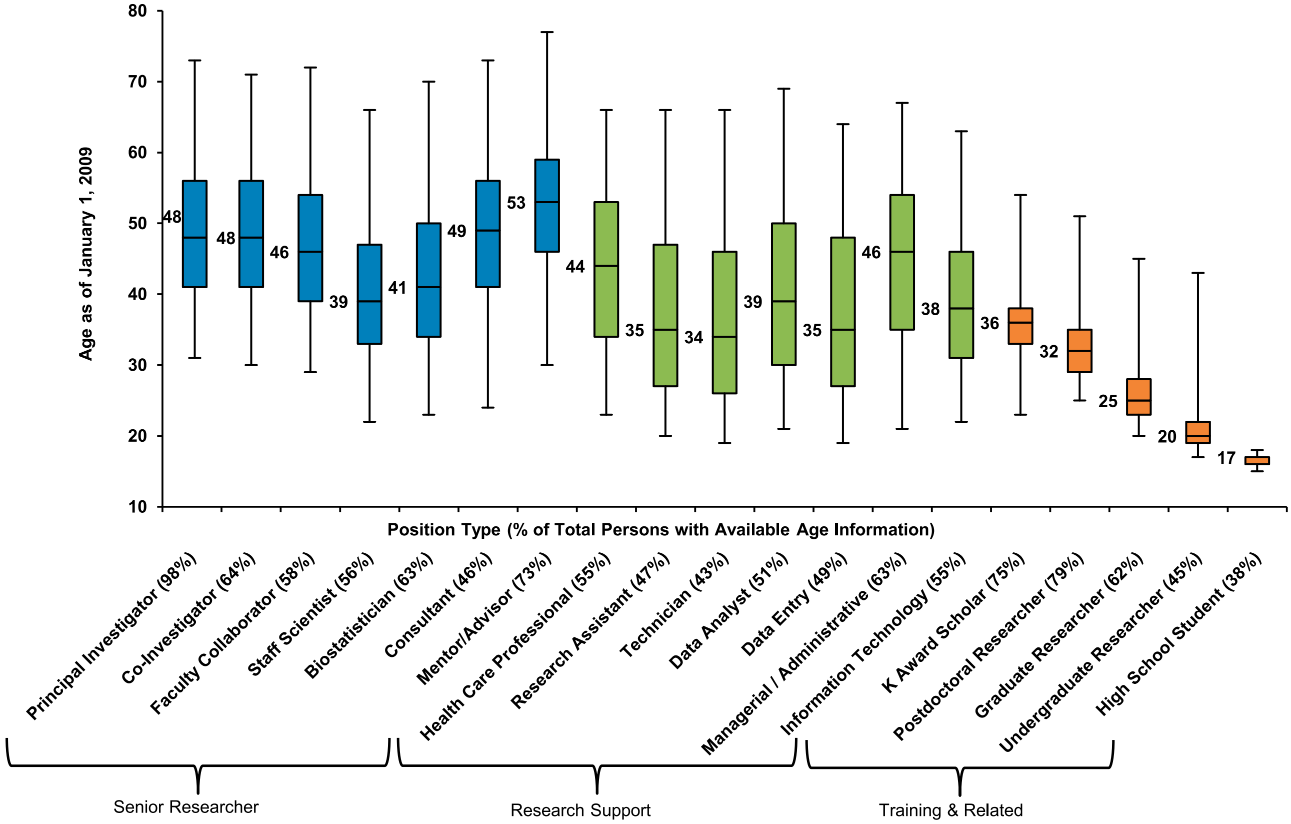

Figure 7. FY 2009 age distribution of persons by position type. PI position type includes MPIs officially indicated on an NIH Grant Application. Labels represent the median age by position. Box edges represent the interquartile range (25–75% of the distribution), and the whisker bars represent the 1st and 99th percentiles of age. Ages >90 and <15 were considered errors and were omitted (0.1%). Excludes positions funded through the ARRA.

NIH support in 2009, were associated with NIH training grants or fellowships (19). However, the GSS uses different methods and captures only students' primary sources of support, reporting this information only for full-time students at degree granting institutions. In addition, the GSS enumerates students at 1 point of time in the year. In contrast, the All Personal Report includes all of NIH's support for part- and full-time graduate students for the entire fiscal year, perhaps accounting for this study's higher counts than the GSS.

The NIH flagship program for research training is the Ruth L. Kirschstein NRSA program, which offers support to undergraduates, graduate students, postdoctoral researchers, and senior fellows in both institutionally (training) and individually administered (fellowships) awards. These awards provide tuition support, stipends, and training-related expense funding at levels that are set annually. NRSA funding is available only to U.S. citizens and permanent residents. In addition, undergraduate training programs are only provided at a limited number of institutions.

TABLE 4. *Number of positions by position type and NRSA status, FY 2009*

Position on grant form, by NRSA status[a]	Positions (*n*)	% of position total	Unique persons (*n*)	% of person total	PYE (*n*)	% of PYE total
NRSA postdoctoral researcher	6,551	20.7	6,520	22.0	5,883	26.5
Other postdoctoral researcher	25,121	79.3	23,182	78.0	16,298	73.5
Total postdoctoral researcher	31,672	100.0	29,702	100.0	22,181	100.0
NRSA graduate researcher	10,784	33.7	10,725	34.1	8,748	42.3
Other graduate researcher	21,257	66.3	20,762	65.9	11,951	57.7
Total graduate researcher	32,041	100.0	31,487	100.0	20,699	100.0
NRSA undergraduate researcher	713	12.2	713	12.3	616	27.8
Other undergraduate researcher	5,146	87.8	5,075	87.7	1,598	72.2
Total undergraduate researcher	5,859	100.0	5,788	100.0	2,213	100.0

Both full- and part-time positions are included. Excludes projects and positions funded through the ARRA. [a]NRSA postdoctoral and graduate researchers are supported by training (T) or fellowship (F) programs, whereas NRSA undergraduate researchers are supported only by training programs. Researchers in the "Other" categories are associated with non-NRSA T and T programs, as well as research grants, such as R01s.

In FY 2009, 21% of postdoctoral, 34% of graduate, and 12% of undergraduate research positions supported by the NIH were funded through NRSA awards. As shown in Table 4, the NRSA training programs represented a larger fraction of the postdoctoral, graduate, and undergraduate PYE than unique persons, because, in contrast to non-NRSA postdoctorates and students, NRSA trainees and fellows are required to devote their full-time effort to the NRSA grant and are generally supported for 12-mo continuous periods (20).

Most postdoctoral, graduate, and undergraduate research positions were supported through mechanisms other than the NRSA training programs (Table 4), including non-NRSA training-related NIH funding opportunities [such as the Fogarty International Research Training Award programs (21) and the NIH Summer Research Experience Programs (22)], as well as through positions working on NIH research grants. Because, according to the GSS, ~51% of postdoctorates in biomedical sciences departments at U.S. institutions were on temporary visas in 2009 (19), the positions on research grants—which do not have citizenship restrictions—are commonly used to support those researchers.

Using the information from IMPAC II and the SED (*http://www.nsf.gov/statistics/srvydoctorates/*), citizenship was determined for the subset of non-NRSA postdoctorates who reported their Commons ID and received an academic doctorate in the United States. The SED is an annual census of all persons who received an academic doctorate from a U.S. institution, and thus it excludes those who received their academic doctorate outside of the United States or lack such a degree (*e.g.,* M.D.-only degree holders). Citizenship status was preferentially obtained from IMPAC II, and supplemented by the information in the SED when IMPAC II citizenship status was unavailable. Individuals were classified as temporary residents if their citizenship status was recorded as a temporary resident in IMPAC II, or their citizenship status was unknown in IMPAC II and they were either not captured in the SED or reported having a temporary U.S. visa in the SED. In this sample, almost 65% of non-NRSA postdoctorates were estimated to be on temporary visas (**Table 5**).

TABLE 5. *Citizenship status of non-NSRA postdoctorates*

Citizenship[a]	% of Total
U.S. citizen total	27.3
Permanent resident total	8.0
Temporary resident total	64.7
Unknown citizenship total	0.1
Total	100.0

Excludes projects and positions funded through the ARRA. [a]Based on postdoctorates who reported having an academic doctorate and an IMPAC II Commons ID (N = 9110). Sources of data: All Personnel Report, IMPAC II Commons Profile, and information reported in the SED at the time of receiving the Ph.D.

From the available demographic information, there were differences in the educational background of the NRSA and other grant-funded postdoctorates. The proportion of NRSA postdoctorates with medical or other health professional doctorates was >35%, whereas <10% of the non-NRSA grant-funded postdoctorates had clinical degrees (**Fig. 8**). This result aligns with NIH policy, which encourages doctoral-level health professionals to receive formal research training through the NRSA program (20). However, because of the larger overall number of postdoctorates on research grants (which are mostly Ph.D. holders), the number of all clinicians (medical doctors, as well as those with other health professional doctorates) on NRSA grants and other grants was about equal (2319 and 2210, respectively).

Study limitations

In its first year of implementation, the information submitted on the All Personnel Report was not electronically validated at the time of submission. Thus, some of the reported data may have been incomplete or inaccurate. Errors encountered in the course of this study include PIs being classified to another role (2%) or not being included on the All Personnel Report (0.4%), non-PIs being reported as PIs (9% of reported PIs on the All Personnel Reports), and duplicate birth dates being provided for all individuals on the same report. Steps were taken to remedy these errors, including using supplemental information from IMPAC II, where possible. Data from IMPAC II rather than the All Personnel Report were used to fully enumerate PIs, fellows, and trainees, and to identify and recode the persons who were misclassified as PIs on the report.

Missing demographic data also made it difficult to identify individuals who devoted effort to more than 1 NIH grant in FY 2009. Overcoming this problem required the construction of a complicated de-duplication algorithm. A standardized unique researcher ID would have saved much effort and increased the ability to accurately identify and quantify research personnel. Current efforts under way to develop and promote the adoption of unique, persistent researcher IDs such as the Federal-Wide Researcher Profile Project [also known as Science Experts Network (SciENcv)] (23) and the Open Researcher and Contributor ID (ORCID) (24), when implemented, will make it much easier in the future to identify persons associated with multiple grants.

Processing the paper-based progress reports presented specific challenges and proved time consuming. Although paper-based reports comprised only 11% of total FY 2009 projects, they represented 37% of extracted roles, because they included complex grant mechanisms, which are composed of multiple projects and, in turn, require more staff to conduct the research. The OCR technology used to extract information from the paper-based forms produced data that required heavy data cleaning, especially because the de-duplication algorithm that translated positions to unique persons relied on matched data, and could not tolerate common OCR errors, such as interpreting a numerical zero as the letter "O." These problems should be eliminated in future enumeration studies, as NIH transitions to the Research Performance Progress Report, which is electronically submitted and includes structured data fields.

Degrees and many occupational position titles were reported as free text, requiring a manual review to code them into standard, analyzable categories. The sheer volume and variation of the degrees, professional certifications and positions titles may have resulted in some misclassification (*e.g.,*

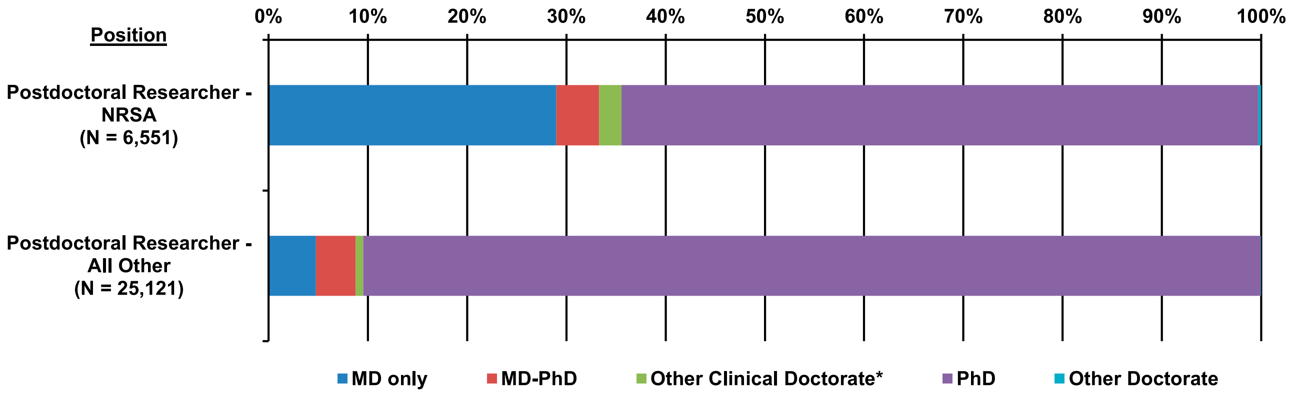

Figure 8. FY 2009 distribution of educational attainment of persons by postdoctorate type. Other Clinical Doctorate excludes M.D. and equivalent degrees and includes D.V.M., Pharm.D., and other patient care degrees. Excludes positions funded through the ARRA.

graduate student research assistants or postdoctoral staff supported by research grants reported only as "research assistants" were misclassified to the Research Support category, rather than to the Training and Related category).

Finally, this study was intended to be a census, but there were significant amounts of data missing, because of the 28% of projects for which there was not an available All Personnel Report. To provide estimates for grants without All Personnel Reports, personnel records were imputed using existing data. There were significant differences in the grant mechanisms supporting imputed and nonimputed projects, however, and therefore differences in direct cost dollars and type of grantee institution as well. SBIR/STTR projects were most likely to require imputation. In contrast, none of the training and fellowship grants (Ts and Fs) needed imputation, because of separate data collection requirements. As a result of these systematic differences, we used both activity code and direct cost dollars in the imputation to ensure that we would not overestimate the position counts for the imputed projects. Demographic characteristics, such as the geographic region of the PI's institution, did not vary between imputed and nonimputed projects. However, almost all of the missing data were from projects in the last year of funding, as All Personnel Reports are not required in the final grant report. We assumed that grant staffing levels were constant across the years of the project. If staffing levels were actually lower (or higher) in the final year of an NIH-funded project, the imputed figures may be overestimates (or underestimates).

Positions were imputed using the direct cost dollars, position type, and activity code. It is possible that a person contributed to both imputed and nonimputed projects during FY 2009. We did not assume all imputed positions to be filled by persons not yet in our sample. Instead, we used the position:person ratio by position type from the existing data records to add the fraction of new persons that could be expected from the imputed projects. This strategy allowed for a reliable estimate of the overall number of persons associated with NIH grants in FY 2009, but did not allow for imputation of individual characteristics of the persons associated with imputed projects. As a result, the estimates for personal information such as age and educational attainment were based on the available, nonimputed sample.

Despite these limitations, this study represents a substantial advance over previous efforts to enumerate the NIH-supported extramural workforce, in that it is based on actual information reported by PIs and their institutions and provides estimates of all positions created and supported by NIH grant funding. Furthermore, until all of the data necessary to characterize the NIH-associated extramural workforce are available electronically, the detailed data produced here can be used to project the size of the NIH-associated workforce in FYs beyond 2009.

CONCLUSIONS

In this first-ever census of the NIH-funded biomedical workforce, we found that in FY 2009, NIH funded 50,885 grant projects, creating 313,049 full- and part-time positions spanning all job functions involved in biomedical research. These positions were staffed by 247,457 people at 2,604 institutions, and devoted 121,465 PYE to NIH grant-supported research. Projections for FYs 2010–2014 indicate that the NIH-funded biomedical workforce has remained relatively stable, despite declines in total direct costs. Although postdoctorates and students filled ~20% of positions in FY 2009, they contributed the largest amount of effort to the projects, almost 40% of all PYE. Most of these students and early career scientists were supported through positions on NIH research grants, rather than NRSA training grants and fellowships. At the postdoctoral level, most positions on NIH research grants were filled by persons on temporary resident visas, highlighting the high concentration of newly trained foreign scientists making contributions to biomedical research in the United States.

FUTURE RESEARCH

Interest in understanding the biomedical research workforce continues to mount. In 2011, a working group of the NIH Advisory Committee to the Director was created and tasked with "developing a model for a sustainable and diverse U.S. biomedical research workforce that can inform decisions about training the optimal number of people for the appropriate types of positions that will advance science and promote health" (3). One of the working group's key findings was a lack of comprehensive data on biomedical researchers. As the first detailed census of the workforce devoting effort to NIH research grants, this study should begin to fill the data gaps and serve as a foundation for future efforts to characterize the extramural biomedical research community and strengthen the evidence base for future biomedical workforce policies. FJ

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