TITLE: An unconventional combined MD/masters-MD/PhD training program leads to a more balanced output of academic physician-scientists

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Abstract

Background: Physician-scientists are a fundamental component of medical research with medical programs throughout Canada invested in training hybrid physician-scientists. Few data exist as to whether programs are generating the diversity, gender equity and numbers of trainees essential for the future of medical research and teaching. Our study aimed to identify factors that contribute to research productivity, diversity and retention of individuals as physician-scientists.

Methods: We completed a retrospective cohort study from 1973-2015 of the University of Calgary Leaders in Medicine Program in Calgary, Alberta. Participants were co-registered in graduate (masters and PhD) and medical degree programs. Primary outcomes included publications and eventual career paths of graduates with individuals were characterized as physicians or physician-scientists based upon these metrics.

Results: Of the 310 individuals who jointly pursued a graduate and medical degree, 136 (44%) were PhD students; 174 (56%) were masters trainees. While in the joint program, male PhD students consistently published more frequently than females. There was no significant difference in publication record between male and female masters students. Of the 161 individuals who were five or more years beyond graduation, 44 (27%) qualified as physician-scientists. Twenty six (41%) PhD students became physician-scientists compared with 18 (18%) masters trainees. Female PhD graduates (20%) were less likely to become physician-scientists then females who completed a masters degree (56%).

Interpretation: By incorporating both masters and PhD students in the training program, our data demonstrate that a greater diversity and number of physician-scientists can be produced who are actively involved in academic research.

Introduction

Physician-scientists remain an endangered species despite decades of training investment. In the 1970s, MD/PhD programs were developed to address the dwindling number of research-trained physicians, individuals capable of speaking the 'dual languages' of science and medicine. Apart from the National Institutes of Health (NIH) analysis of the outcomes of the Medical Scientist Training Programs (1, 2), little data exist for individual MD/PhD programs and certainly not in Canada. This poses several questions: are these programs achieving their overall goal to generate physicians actively involved in academic research; and, might the structure of individual programs impact training outcomes for physician-scientists?

Analyzing outcomes of MD/PhD programs is complicated by the fact that there is no universally accepted definition of a 'physician-scientist,' nor are there optimal metrics for identifying successful outcomes. Further, many physicians who actively contribute to research have not formally received training through an MD/PhD program. These individuals include those who have received training either through masters programs or within a clinical residency post-graduate training environment.

The traditional route most physician-scientist training programs employ follows a K-selection model where a small number of high-level students are nurtured throughout the course of a structured MD/PhD program. Although subtle differences exist between institutions with regard to admission policies and standards, there are commonalities among programs. These include providing adequate mentorship, financial support and encouraging translational research initiatives. Generally, students in MD/PhD programs complete their preclinical medical training prior to entering full time research. Upon completion of graduate work, students return to the clinical portion of the medical curriculum, taking a total of seven to eight years to finish the academic program.

Alternative models to training physician-scientists exist. In particular, the University of Calgary has developed a unique training model (3) whereby students from both masters and doctoral programs are eligible for entry in following with an r-selection model. Research programs are also not limited to the basic sciences, allowing for an expanded diversity of 'unconventional' research programs ranging from philosophy, engineering and the social sciences. Students may enter the physician-scientist pathway at multiple points during their training, allowing for flexibility in accommodating individual research programs. The joint-program does not have a set student quota, unlike sister programs in Canada, expanding the number of graduates receiving physician-scientist training.

Given the dearth of data analyzing the outcomes of graduates from individual physician-scientist training programs, we examined the career and research outcomes of the physician-scientist training program at the University of Calgary. Our hypothesis was that a more flexible approach to training physician-scientists would in turn affect graduate outcomes such as research productivity, diversity of subspecialty choice and gender balance.

Methods

Data Collection for Graduate Degrees and Publications

Using alumni data from the Cumming School of Medicine and University of Calgary PRISM database, a retrospective cohort study was conducted on individuals who jointly pursued graduate and medical studies at the University of Calgary from 1973–2015. Student name, graduating degree, and graduation year for all joint-degree students were identified using the MD alumni data. PRISM, which indexes all graduate theses from the University of Calgary, was used to identify the sex of both the student and graduate supervisor, graduate degree department, and confirm both the graduate degree acquired and year of graduation. When available, maiden names were noted and incorporated into searches. Data were collected by three reviewers (JB, AF, NN) with consensus reached on each individual.

Publication information was identified for each graduating student using both the National Institutes of Medicine PubMed and Web of Science databases. Publications were stratified as those occurring: 1) before; 2) during; or 3) following admission in the joint-program. Level of authorship was extracted as: 1) first-author; 2) second-author; 3) senior-author; or 4) any other level of authorship. The nature of the published study was categorized as: 1) original; or 2) review. Papers consisting of experimental work or epidemiological systematic reviews were considered original, whereas literature reviews or commentaries were considered review.

Career Path Identification

Residency matching and current occupation were identified through the provincial Colleges of Physicians and Surgeons and Canadian College of Family Physicians. Current students were excluded from residency-related analyses. Current occupation was defined as 1) student for current joint-program students; 2) resident; 3) fellow; 4) physician; and 5) physician-scientist. Current students and those graduated from the program for less than five years were excluded from physician-scientist analyses, as they have not had the opportunity to complete residency and fellowship programs. In keeping with criteria outlined above, physician-scientists were defined as having: 1) a minimum of seven total publications; 2) one original publication in the last five years as either first- or senior-author; and 3) graduated from the joint-program for more than five years. If one of these criteria were not met, the individual was classified as a physician.

Publication record was analyzed as a continuous variable using Welch's t-test for unequal variances. Means and accompanying 95% confidence intervals (CI) were calculated for each publication category and stratified by sex of student and graduate degree. Post-hoc sensitivity analyses were conducted removing two individuals with greater than 100 publications as these could skew the mean publication estimates. Career path was analyzed as a categorical variable using Pearson Chi-squared tests looking separately at residency and occupation (with a focus on physician compared to physician-scientist).

To identify the association between exposures of interest (sex of student, year of graduation, degree obtained, and number of publications while in the joint program) with career path, stepwise logistic regression was utilized and odds ratios (OR) and accompanying 95% CIs were reported. For ease of interpretation, number of publications in the joint program was stratified according to rounding up the mean publications for the purpose of this analysis with 1) fewer than four publications in one category;

and 2) four or greater publications in the other. Effect modification was explored by sex of student and degree obtained. Graduation year was explored as both a continuous and categorical exposure stratified in five-year increments, with current students explored separately from graduates.

Statistical analyses were performed with an a-priori alpha of 0.05. Two-sided p-values were reported. All analyses were conducted using Stata 11.2. Figures were created using Prism v5.0.

Results

A total of 310 individuals were part of the joint-program from 1973 until 2015. Of those, the majority (n=236, 76.1%) were enrolled in science-based graduate programs. Of the many graduate programs offered by the faculty (Table 1), students were most commonly enrolled in Medical Science (n=96, 31%), Neuroscience (n=55, 18%) and Biological Sciences (n=24, 8%). Those in non-science programs comprised 12% of the total joint-program population (n=37). This pattern of distribution between programs differed somewhat amongst the masters trainees compared with the doctoral students (Table 1). Of the 174 masters students, 49% were female whereas 40% of the 136 PhD students were female (Figure 1A and 1B).

Research Productivity

Current and former PhD students consistently published more than current and former masters students (Table 1 and Figure 2). There were no significant differences in publications between female and male masters students (p-values >0.1) although male PhD students published more frequently than female PhD students. This difference was most significant for the mean number of first-author publications (mean 4.96; 95% CI 3.61-6.31 for males; mean 3.03; 95% CI 2.20-3.87 for females) and second-author publications (mean 2.63; 95% CI 1.65-3.61 for males; mean 1.22; 95% CI 0.83-1.60). The mean number of publications in the joint-program was higher for males than females (mean 5.72; 95% CI 4.44-7.00 versus mean 4.18; 95% CI 3.26-5.10). Male students significantly more often had four or more publications while in the joint-program compared to females ($p < 0.04$). After removing the two individuals with >100 publications, sensitivity analyses demonstrated more marked differences between male and female publication frequency in every category of publications except for publications before entry into the joint-program (Table 2). During the joint-program, for example, male PhD students had significantly more publications than female PhD students (mean 5.73; 95% CI 4.44-7.03 versus mean 4.09; 95% CI 3.17-5.01).

Career Path Identification

Of the 310 individuals, 68 (22%) were current students excluded from residency analyses. Of the 242 joint-program graduates, the largest proportion (n=67, 27.7%) matched to family medicine, followed by internal medicine (n=55, 22.7%) (Table 3). Female graduates, masters students, and students with fewer than four publications while in the joint-program were significantly more likely to match to family medicine than other programs. The selection of residency programs was compared between physicians versus physician-scientists (Figure 3). The most common residency program for non-physician-scientists was family medicine, followed by internal medicine and pediatrics. Alternatively, the most commonly selected residency program was internal medicine, followed by neurology and pediatrics for physician-scientists.

The covariates that populated the final stepwise logistic regression model were sex of student and fewer than four publications. Female students had 1.96 times the odds of male students of matching to family medicine after adjustment for publications (OR 1.96; 95% CI 1.10-3.52). Students with fewer than four publications had 2.67 times the odds of matching to family compared to students with four or more publications after adjustment for sex (OR 2.67; 95% CI 1.33-5.40). Effect modification was not identified. Neither sex of student, graduate degree, nor publication record in the joint-program were associated with matching to internal medicine.

Of the 161 eligible individuals (those who were five or more years beyond graduation) 27% (n=44) became physician-scientists (Table 2). Of the 63 PhD graduates of the joint-program, 41% (n=26) became physician-scientists compared with 18% (n=18) of the 98 masters graduates. Of the 26 PhD graduates who became physician-scientists, 20% were female. In contrast, 56% of the 18 masters graduates who became physician-scientists were female (Figure 1). Overall, PhD graduates with four or more publications while in the joint program were significantly more likely to become physician-scientists.

The only covariate to populate the final stepwise logistic regression model was having four or more publications while in the joint-program. Students with four or more publications while in the joint-program had 7.26 times the odds of becoming a physician-scientist compared to those who did not (OR 7.26; 95% CI 3.37-15.67). After adjustment for sex, degree, graduation year, and four or fewer publications while in the joint-program, internal medicine residents had 4.44 times the odds of becoming a physician-scientist compared to those in other residencies (OR 4.44; 95% CI 1.64-12.01), and family residents had 0.10 times the odds of becoming a physician-scientist (OR 0.10; 95% CI 0.02-0.48). Effect modification was not identified by sex or degree.

Interpretation

Breaking Tradition

Medical school entrants have changed markedly over the last 50 years with increased diversity of premedical education including students pursuing non-traditional degrees such as humanities or business (4). Furthermore, over 20% of students entering medical school have already completed a graduate degree (5). In our study, 310 individuals who jointly pursued graduate and medical studies at a single institution, one-quarter of the graduates continued research as physician-scientists. Of those, 40% were masters graduates – contributors that may have been lost in more traditional programs.

Physician-scientists generally receive clinical training through more research-oriented specialties, predominantly internal medicine. While our training model continues to support this trend, an increasingly large proportion of physician-scientists arise from a diverse array of specialties including family medicine and physiatry (6). To date, this wealth and depth of educational diversity has not been captured. We propose that adaptation of our physician-scientist training structure to other programs may help engage future research leaders in medicine that may otherwise be underutilized.

Involvement of Women

In our study, the factor that best predicted future involvement as a physician-scientist was having four or more publications while in the joint-program. Our findings are corroborated by another study comparing general surgeons who received physician-scientist training versus those who did not; trainees who received combined training published significantly more often (7). In our dataset, male students more often achieved the four-publication milestone than females, regardless of degree. This suggests that there may be issues during the course of the joint-program preventing female students from attaining the publication threshold predictive of becoming a physician-scientist. Differences in mentorship may be an area of discrepancy affecting females' publication levels in the joint-program.

While PhD graduates who became physician-scientists were overwhelmingly male, the proportion of masters graduates who qualified as physician-scientists by our criteria was nearly evenly distributed between females and males. Thus, investment in the training of MD/masters students not only increases the physician-scientist pool, but also leads to the training of more female physician-scientists. This outcome is particularly important as the sex divide amongst active physician-scientists has long been male-dominated (6, 8). Reasons for this are multifactorial and difficult to isolate, but it is possible that length of training time might impact decisions to pursue further training. Based on our data, a role for shorter clinical-research training programs exists.

Addressing Costs

Other factors external to training time are likely contributing to the decline in physician-scientists including the increased challenge of obtaining research funding, and escalating demands for physician-scientists to provide patient care service to enable salary cost-recovery (9). The cost of education can also serve as a barrier. The Canadian Institutes for Health Research recently eliminated their longstanding funding for MD/PhD students in spite of a 2011 report highlighting the integral role of the physician-scientist (10-14). Without external funding, pursuing both graduate and medical training can be an expensive personal undertaking. It has long been perceived that the decline in physician-scientists is directly correlated with debt-burden associated with prolonged training programs (9, 15).

Limitations

Our study, while a first-in-kind at a Canadian institution, has its limitations. The first issue is that there is no consensus definition of a physician-scientist. We defined physician-scientists as graduates who had clear contributions to research after graduation according to their peer-reviewed publication record. While leading an independent research program as a principal investigator represents a key attribute of a physician-scientist, we feel that this definition is too restrictive, and does not account for those individuals who contribute as collaborators. A second issue is that our analyses did not include grant-funding data as this information was incomplete and only partially publicly available. Many researchers have sources of funding apart from national granting agencies, so incorporating grant data only from publicly available sources (e.g., tri-council funding agencies), while excluding others (e.g., disease-specific grants from organizations), would not be a true reflection of a scientist's funding situation.

Conclusion

Physician-scientists are an integral part of the medical community and training these 'bilingual' professionals is necessary for driving innovations in research and patient care. By incorporating both masters and PhD students in the training program, a greater number of active physician-scientists can be produced. Our study supports the need for strong mentorship for female students, a demographic that has been underrepresented in the past. Further, encouraging masters-trained physicians may be a novel mechanism to deal with the discrepancy between male and female trainees. We hope that this innovative training approach will encourage graduates to remain active in clinical medicine and academic research while rectifying the worrisome trend of the decline of the physician-scientist.

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Figure Legends

Figure 1. Demographics of Graduates by Gender and Career Classification

The total number of graduates from the joint-program were classified by gender and by graduate degree (Fig 1A and 1B). The graduates were also graphed by gender, graduate degree and subsequent career classification (Fig 1C and D). Those graduates classified as physician-scientists (13 female and 31 male) were separated by graduate degree obtained (Fig 1E and 1F).

Figure 2. Mean Publications while in Joint Program Stratified by Degree and Sex

Graduates were segregated by graduation period and graduate degree with the mean number of publications per graduate plotted.

Figure 3. Residency Distribution Stratified by Career Path

Graduates were classified based on their career classification (physician vs physician-scientist) and plotted based on their entrance into specific residency program.

(Note figures have been uploaded as separate files)

Figure 1. Demographics of Graduates by Gender and Career Classification

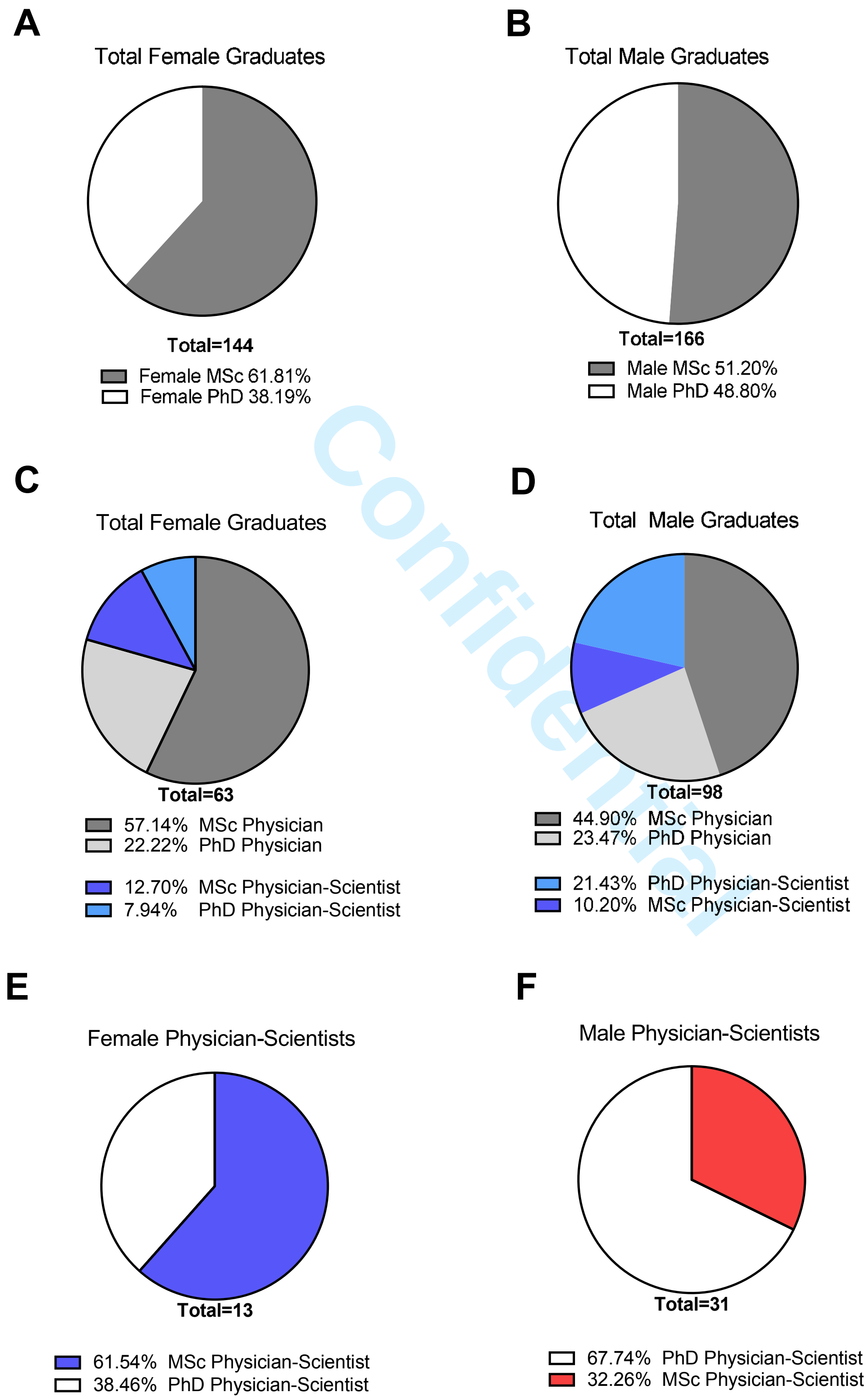
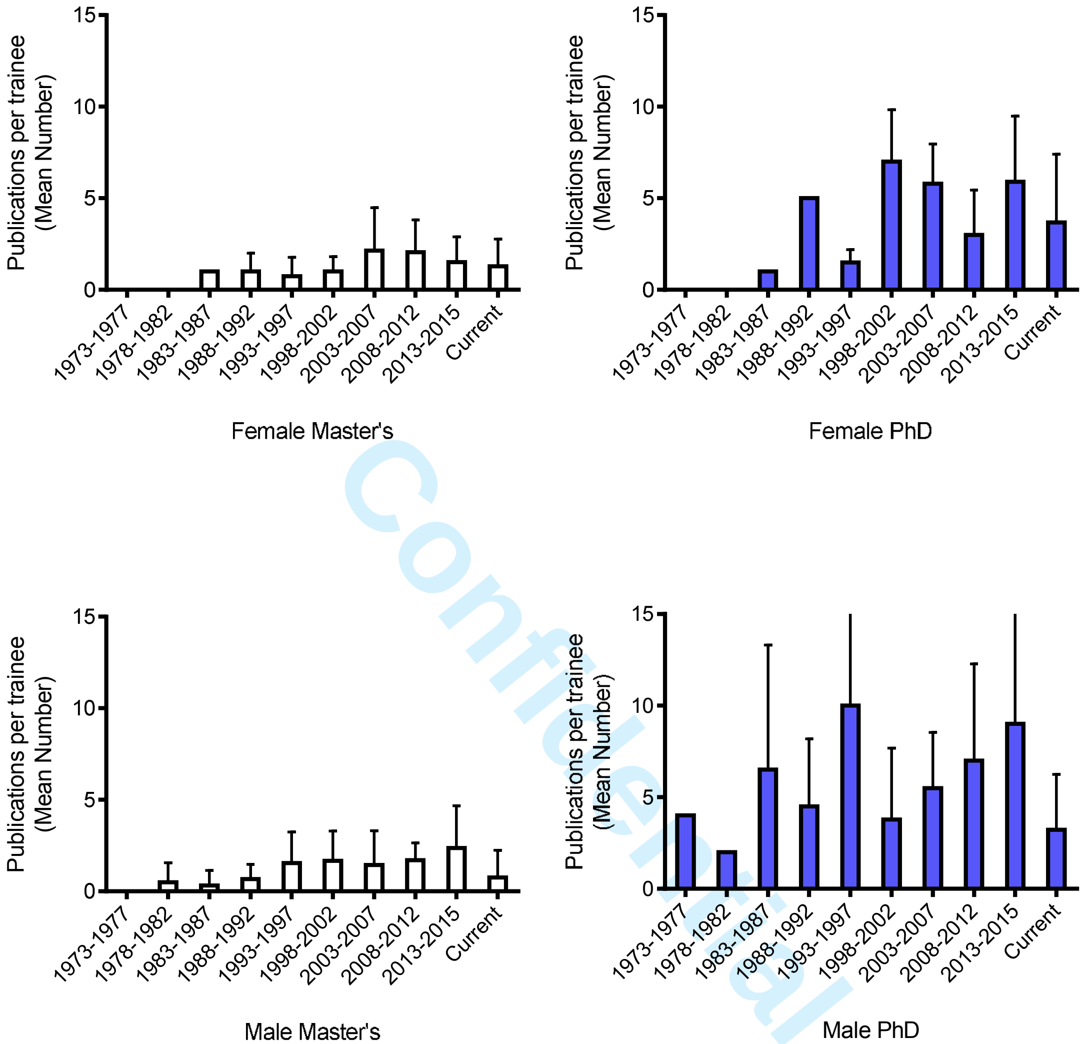


Figure 2. Mean Publications while in Joint Program Stratified by Degree and Sex



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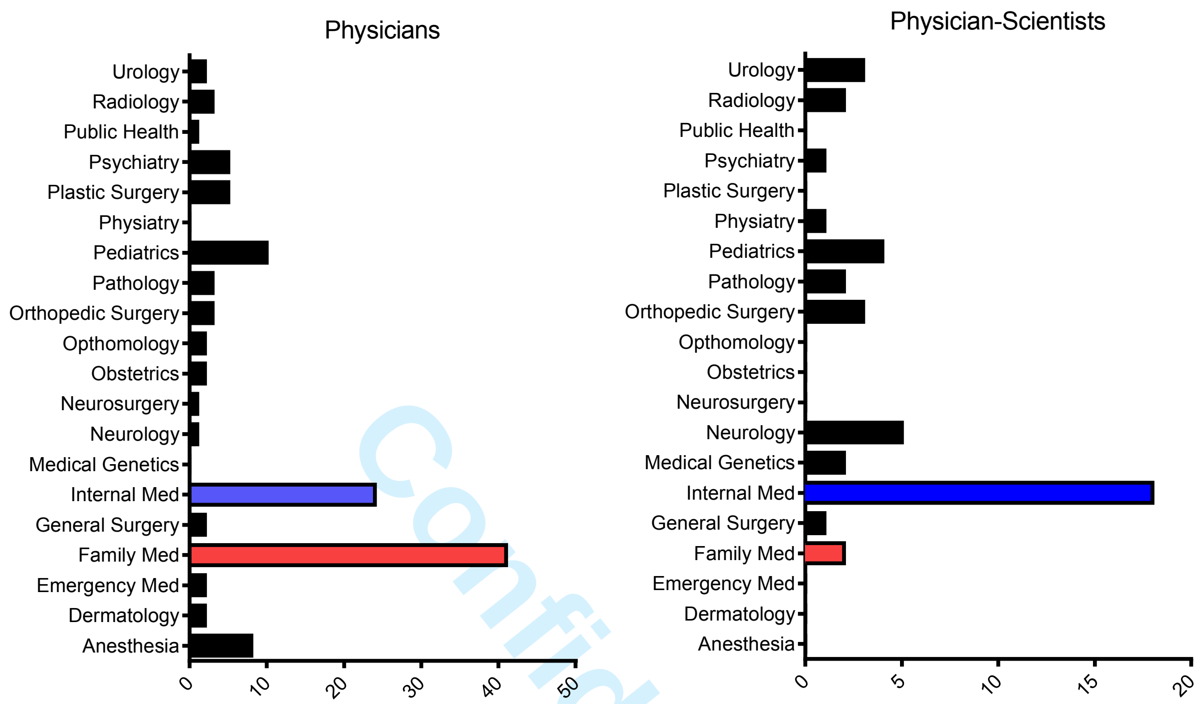

Residency distribution stratified by career path

Table 1. Proportion of joint-program students in each graduate program as PhD or masters students from 1973 to present

Graduate program	Total number of students in each program	Number and (%) of PhD students in each program among all PhD students	Number and (%) of masters students in each program among all masters students
BISI	24	11 (8.09%)	13 (7.47%)
BUSI	4	0 (0.00%)	4 (2.30%)
CHEM	5	2 (1.47%)	3 (1.72%)
ENGG	12	8 (5.88%)	4 (2.30%)
KNES	15	8 (5.88%)	7 (4.02%)
MATH	2	0 (0.00%)	2 (1.15%)
MDBC	17	6 (4.41%)	11 (6.32%)
MDCH	19	6 (4.41%)	13 (7.47%)
MDCV	14	8 (5.88%)	6 (3.45%)
MDGI	13	9 (6.62%)	4 (2.30%)
MDIM	12	7 (5.15%)	5 (2.87%)
MDMI	10	6 (4.41%)	4 (2.30%)
MDNS	55	29 (21.32%)	26 (14.94%)
MDSC	96	32 (23.53%)	64 (36.78%)
PHIL	6	2 (1.47%)	4 (2.30%)
PSYC	6	2 (1.47%)	4 (2.30%)
TOTAL	**310**	**136 (100.00%)**	**174 (100.00%)**

BISI: Biological Sciences; BUSI: Business; CHEM: Chemistry; ENGG: Engineering (Mechanical, Chemical and Biomedical); KNES: Kinesiology; MATH: Mathematics; MDBC: Medicine, Biochemistry and Molecular Biology; MDCH: Medicine, Community Health Sciences; MDCV: Medicine, Cardiovascular and Respiratory Sciences; MDGI: Medicine, Gastrointestinal Sciences; MDIM: Medicine, Immunology; MDMI: Medicine, Microbiology and Infectious Diseases; MDNS: Medicine, Neuroscience; MDSC: Medicine, Medical Science; PHIL: Philosophy (Sociology, English, Education, Political Science); PSYC: Psychology

Table 2. Characteristics of physician-scientists by graduating degree from joint-program

	PhD (n=26)	Masters (n=18)
Sex, n (%)		
Male	21 (80.8%)	10 (55.6%)
Female	5 (19.2%)	8 (44.4%)
Residency, n (%)		
Family	1 (3.9%)	1 (5.6%)
General Surgery	0 (0.0%)	1 (5.6%)
Internal Medicine	10 (38.5%)	8 (44.4%)
Medical Genetics	1 (3.9%)	1 (5.6%)
Neurology	3 (11.5%)	2 (11.1%)
Orthopedic Surgery	2 (7.7%)	1 (5.6%)
Pathology	1 (3.9%)	1 (5.6%)
Pediatrics	4 (15.4%)	0 (0.0%)
Physiatry	0 (0.0%)	1 (5.6%)
Psychiatry	0 (0.0%)	1 (5.6%)
Radiology	1 (3.9%)	1 (5.6%)
Urology	3 (11.5%)	0 (0.0%)
Total publications in joint-program, mean±standard deviation	6.4±6.5	2.9±2.4
Male	6.7±7.2	1.9±2.0
Female	5.2±2.6	4.3±2.4