

Predictors of sustained research involvement among MD/PhD programme graduates

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CONTEXT MD/PhD programmes provide structured paths for physician-scientist training. However, considerable proportions of graduates of these programmes do not pursue careers in research consistent with their training.

OBJECTIVES We sought to identify factors associated with sustained involvement in research after completion of all postgraduate training.

METHODS Anonymised data from a national survey of Canadian MD/PhD programme graduates who had completed all physician-scientist training ($n = 70$) were analysed. Multivariable logistic regression was used to measure the associations between characteristics of graduates and five indicators of sustained research involvement following postgraduate training: (i) protected research time in the current appointment; (ii) percentage of time dedicated to research; (iii) planned future involvement in research; (iv) role as a principal investigator on a recent funded project, and (v) receipt of funding from a federal granting agency since graduation.

RESULTS The majority of graduates were significantly involved in research on the basis of at

least one outcome. Completion of a research fellowship, number of first-authored or co-authored manuscripts published during MD/PhD training, and duration of MD/PhD training were positively associated with continued research involvement. Completion of a Masters degree prior to MD/PhD training, female gender, debt greater than CAD \$50 000 at completion of training, and pursuit of a clinical specialty other than internal medicine, paediatrics, neurology, pathology and the surgical specialties were negatively associated with sustained research involvement.

CONCLUSIONS Most MD/PhD programme graduates remain significantly involved in research, but this involvement often does not correspond to traditional physician-scientist roles, in which a majority of time is dedicated to research. To minimise loss of investment in physician-scientist training, MD/PhD programmes should prioritise research productivity during training and the pursuit of additional research training during residency, and policymakers should establish stable sources of funding to reduce debt among graduates. Our data suggest further study is warranted to identify interventions to reduce attrition among female MD/PhD programme graduates.

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 INTRODUCTION

Physician-scientists pursue careers in medicine that integrate clinical practice with scientific research. The combination of clinical and research training affords physician-scientists the perspective and skill set to address research issues with direct relevance to clinical practice. Accordingly, multiple studies have found that physician-scientists make important contributions to translational research.^{1–8}

Combined Doctor of Medicine/Doctor of Philosophy (MD/PhD) programmes provide a structured path that enables physician-scientist trainees to receive both medical undergraduate and doctoral research training. Although the structure of MD/PhD programmes varies among institutions and internationally, Canadian programmes are completed after a median of 7.7 years.¹ Generally, trainees complete the first year or two years of undergraduate medical education before completing PhD studies over a period of 3 to 5 years. Trainees then return to undergraduate medical education for the final 2–3 years of the programme.

Collectively, MD/PhD programmes represent a significant investment of federal, provincial and institutional funding. Within Canada, the majority of MD/PhD programme graduates pursue careers consistent with their training, completing residencies and postgraduate fellowships, securing faculty appointments at academic institutions, and attaining competitive research funding.¹ This suggests that funding for MD/PhD programmes generally meets the objective of training physician-scientists for research-intensive careers. However, analyses within Canada¹ and the USA^{9,10} have repeatedly found that 14–16% of MD/PhD programme graduates eventually exit research entirely in favour of careers in private practice. Further, within Canada, a majority of graduates with faculty appointments (62%) do not engage in research at the level typically associated with a physician-investigator or physician-scientist role as they dedicate <50% of working time to research.¹

To date, the factors that determine sustained involvement in research after all training has been completed have not been well defined, in part as a result of the lack of outcomes data that directly evaluate participation in research. In the absence of such data, investigators have analysed outcomes that reflect academic careers more generally. Andriole

and Jeffe¹¹ found that factors associated with full-time faculty appointment among US MD/PhD graduates included attending a school with medical scientist training programme (MSTP) funding and completing a research year during residency, whereas debt at graduation and completing a surgical residency were negatively associated with likelihood of full-time faculty appointment. Brass *et al.*⁹ suggested that graduates of some US residency programmes, notably those in family medicine, emergency medicine, dermatology and ophthalmology, were more likely to pursue careers in private practice. Data on National Institutes of Health (NIH) grant application rates further indicate that female physician-scientists are significantly less likely than their male counterparts to be funded by research project grants.¹² Given the investment of public funds in physician-scientist training, it is reasonable to ask whether there are identifiable factors associated with sustained research involvement following the completion of all physician-scientist training, using outcomes data that directly reflect research effort.

We recently conducted a national survey of Canadian MD/PhD programme graduates in which we collected outcomes data designed to directly evaluate sustained research involvement. The objective of the present study was therefore to identify predictors of continued involvement in research following the completion of physician-scientist training among Canadian MD/PhD programme graduates. Additionally, in view of the extensive literature documenting gender differences in physician-scientist training and career advancement, including increased attrition in MD/PhD programmes and during the transition to independence,^{12,13} we investigated the relationship between sustained research involvement and gender.

 METHODS

We collected outcomes data for alumni of eight Canadian MD/PhD programmes by conducting a national survey of Canadian MD/PhD programme alumni (University of British Columbia Behavioural Research Ethics Board H15-02871).^{1,14} The survey, which was conducted between November 2015 and October 2016, consisted of 41 questions designed to evaluate the demographic characteristics, education, career trajectory, publication and funding records, debt, and career and lifestyle satisfaction of Canadian MD/PhD programme graduates who had

graduated before September 2015. The survey was administered using survey tools in Google Forms. In collaboration with individual programmes, graduates were contacted up to six times by e-mail, twice by telephone and once by mail. In total, 139 of 186 (75%) graduates of the eight participating MD/PhD programmes completed the survey. Response rates at individual schools ranged from 50% to 100% (median: 81%). The study population ($n = 70$) included graduates who had completed all training, defined by their self-reporting that all training was complete and that they did not hold the title of clinical or research fellow. Individuals meeting these criteria had graduated from Canadian MD/PhD programmes between 1990 and 2012. Because there is no coordinated system for tracking MD/PhD programme graduates within Canada, as is required for US MSTPs that receive National Institute of General Medical Sciences (NIGMS) funding, we were able to collect only limited information about non-responders. However, there was no response bias defined by a significant association between time since graduation and propensity to respond to the survey. The complete survey is provided in Appendix S1.

We considered five outcomes as indicators of sustained research involvement: (i) presence of protected research time in the current appointment; (ii) total percentage of time dedicated to research in the current appointment; (iii) planned substantial involvement in future research; (iv) having acted as principal investigator (PI) on a funded project within the previous 36 months, and (v) receipt of funding from a federal granting agency since completion of a combined MD/PhD degree. These independent variables were selected based on factors that have been suggested in the literature to reflect the degree of research involvement among clinician-scientists. In particular, protected research time, during which the investigator is released from other responsibilities such as those for clinical practice or teaching, has been suggested to be essential if physician-scientists are to establish and lead independent research programmes as faculty members.^{15,16} The percentage of time an investigator dedicates to research is similarly an indicator of the depth of research involvement⁹ and concern has been expressed about insufficient support for physician-scientists who can dedicate 50% or less of their time to research within Canada.² Planned substantial involvement in future research was previously assessed in a survey of MD/PhD programme matriculants.¹⁰ We therefore

included this factor in our analysis, reasoning that as the majority of MD/PhD programmes in Canada are relatively young, the median age of the survey population was expected to be low and consequently many graduates who had completed all training would be early-career investigators. Accordingly, planned substantial involvement in future research may be a more robust indicator of research involvement than the holding of competitive funding or protected research time among investigators who are still establishing independent careers. Finally, research funding has also been investigated previously as an indicator of sustained research involvement among MD/PhD programme graduates.⁹ These outcomes do not limit our assessment to basic science, but may also comprise involvement in clinical and translational research.

To confirm the accuracy of self-report data, we used Google Scholar to manually investigate the publication records of the five most recent graduates who reported publishing five or more papers as first authors and 10 or more as co-authors during MD/PhD training. In all five cases, these records were consistent with the self-report data.

Nine variables were considered as potential predictors of sustained research involvement, including gender, debt at completion of training, clinical specialty, completion of a clinical fellowship, completion of a research fellowship, completion of a Masters degree prior to MD/PhD training, length of time spent in an MD/PhD programme, and numbers of, respectively, first-authored and co-authored manuscripts published during MD/PhD training. Gender, debt at graduation, clinical specialty and completion of additional research training during or after residency have previously been considered in the context of full-time faculty appointment¹¹ or pursuit of a career in private practice⁹ among MD/PhD programme graduates. Completion of a Masters degree or clinical fellowship, time to MD/PhD programme graduation, and numbers of first-authored and co-authored manuscripts published during MD/PhD training were variables collected and analysed here for the first time. We hypothesised that the completion of a Masters degree might reflect a stronger interest in research and therefore correlate with sustained research involvement, whereas completion of a clinical fellowship might conversely reflect a predominant interest in clinical practice. Time to MD/PhD programme graduation was analysed on

the basis of the structure of Canadian MD/PhD programmes, which are heterogeneous with respect to the time mandated for the completion of the PhD portion of the degree. Some programmes specify that the PhD thesis should be completed within 3 years, but offer the opportunity to extend research training to 4 years either in order to improve publication records and competitiveness for subsequent scholarships and salary awards, or because the pace of the trainee's research would not permit that person to complete PhD studies otherwise. Other programmes do not place a fixed limit on the duration of the PhD in order to account for variable time requirements for thesis completion in different fields of science and in different research projects. We speculated that increased time to graduation might allow trainees to prepare more competitive applications for subsequent research-intensive positions and therefore might correlate with sustained research involvement.

Debt at graduation was measured within the survey in categories of no debt, debt of less than CAD \$20 000, debt of CAD\$20 000–50 000, debt of CAD \$50 000–100 000, and debt of greater than CAD \$100 000. To improve statistical power, here we categorised debt according to whether it was greater than CAD\$50 000 or less than CAD\$50 000 (reference group). Similarly, data on the number of first-authored papers published during MD/PhD training were collected in categories of zero, one, two, three, four and five or more, and categorised as up to three (reference group) and four or more. Data concerning the number of co-authored papers published during MD/PhD training were collected in categories of zero, one to three, four to six, seven to nine and 10 or more, and categorised as up to six (reference group) and seven or more. Following a recent analysis of US MD/PhD programme graduates,¹¹ we created a three-category variable for clinical specialty, consisting of 'internal medicine, paediatrics, neurology or pathology' (historically the most common specialties in analyses of both Canadian¹ and US⁹ MD/PhDs, and used as the reference group); surgical specialties, including all surgical specialties recognised by the American College of Surgeons,¹⁷ and other or unknown, including all other specialties and responses in which no specialty was provided.

We performed independent multivariable logistic regressions for the four binary outcome variables (presence of protected research time at current appointment, planned substantial involvement in

future research, having acted as PI on a funded project within the previous 36 months, and receipt of funding from a federal granting agency since completion of a combined MD/PhD degree) and linear regressions for the percentage of time dedicated to research in the current appointment, on each potential predictor. In each case, we controlled for gender and time since MD/PhD programme graduation based on a review of the literature, which revealed these factors as potential predictors of research success.^{18–21} Additionally, we performed univariable regressions to analyse relationships between gender and outcome variables.

Statistical analysis was performed in R VERSION 3.3.1 (R Foundation for Statistical Computing, Vienna, Austria). Two-sided p-values of <0.05 were considered to indicate differences of statistical significance.

RESULTS

Descriptive statistics

Respondents ($n = 70$) had completed their MD/PhD training a mean \pm standard deviation (SD) of 12 ± 5 years before completing the survey (Table 1). Respondents reported employment at academic institutions ($n = 59$), in private or hospital clinical practice ($n = 17$), at government or private research institutes ($n = 2$) or in industry ($n = 1$); respondents were able to select more than one appointment type. Graduates reported dedicating an average of 34% of their time to research in their current appointment. Among individuals appointed at the level of assistant professor or higher, this proportion rose to 43%. In total, 37 graduates (53%) had acted as PIs on funded projects during the previous 36 months and 29 (41%) had been awarded funds from a major federal granting agency since their completion of the MD/PhD. Overall, 44 graduates (63%) had protected research time and 48 (69%) planned substantial future involvement in research. Each of these five outcomes independently indicates significant involvement in research. Thus, 55 graduates (79%) were significantly involved with research on the basis of having at least 50% of their work time protected for research, or answering yes to at least one of the four binary outcome questions (presence of protected research time in the current appointment, planned substantial involvement in future research, having acted as PI on a funded

Table 1 Characteristics of MD/PhD programme graduates (n = 70) of eight Canadian universities who had completed all training

Variable Number	Number	%
<i>Dependent variables: indicators of sustained research involvement</i>		
Protected research time in the current appointment		
Yes	44	63
No	26	37
Percentage of time dedicated to research in the current appointment, number (% of time)		
Mean ± SD	34 ± 27	
Missing value	1	
Minimum	10 (0 %)	14
Maximum	4 (80 %)	6
Planned substantial involvement in future research		
Yes	48	69
No	22	31
Principal investigator on a funded project within the previous 36 months		
Yes	37	53
No	33	47
Receipt of federal granting agency funding since completing MD/PhD		
Yes	29	41
No	41	59
<i>Confounding variables</i>		
Gender		
Female	13	19
Male	57	81
Time since graduation, years		
Mean ± SD	12.0 ± 5.0	
Minimum	4	
Maximum	26	
<i>Independent variables</i>		
Debt at completion of training		
≥CAD\$50 000	19	27
<CAD\$50 000	51	73
Clinical specialty		
Internal medicine/paediatrics/neurology/pathology	34	49
Surgery	9	13
Other	27	39
Completion of a clinical fellowship		
Yes	44	63
No	26	37

Table 1 (Continued)

Variable Number	Number	%
Completion of a research fellowship		
Yes	25	36
No	45	64
Completion of Masters degree prior to MD/PhD		
Yes	13	19
No	57	81
Time spent in an MD/PhD programme, years		
Mean ± SD	7.4 ± 1.4	
Missing value	3	
First-authored manuscripts published during MD/PhD training, n		
≥4	34	49
0–3	35	50
Co-authored manuscripts published during MD/PhD training, n		
≥7	27	39
0–6	43	61
SD = standard deviation.		

project within the previous 36 months, and receipt of funding from a federal granting agency since the completion of a combined MD/PhD degree). The distributions of the nine independent variables are summarised in Table 1.

Univariable regression

When data were adjusted for time since graduation, men had significantly greater odds than women of having served as PI on a funded project within the previous 36 months (Table 2). Further, on average, men additionally dedicated 20% more time to research than women in their current appointment. Remarkably, female gender was negatively associated with sustained research involvement despite the fact that the odds of completing a research fellowship were comparable between men and women (adjusted odds ratio 2.1, 95% confidence interval [CI] 0.56–10; p = 0.31), and on average men took less time to graduate (beta: -1.0; 95% CI -1.9 to -0.14; p = 0.024) when data were controlled for time since graduation.

Table 2 Results from multivariable regression models of the relationships between categorical indicators of sustained research involvement and independent variables, adjusted for gender and time since graduation (years), for Canadian MD/PhD programme graduates who had completed all training (n = 70)

	Adjusted odds ratio (95% CI)			
	Protected research time in current appointment	Planned substantial involvement in future research	PI on a funded project during the previous 36 months	Receipt of funding from a federal granting agency since completing training
Gender				
Male	3.3 (0.96–12.0)	3.5 (1.0–13.0)	5.4 (1.3–30.0)*	1.1 (0.31–4.0)
Female	Reference	Reference	Reference	Reference
Debt at completion of training				
≥CAD\$50 000	0.37 (0.12–1.1)	0.33 (0.098–1.0)	0.22 (0.051–0.82)*	0.27 (0.068–0.88)*
<CAD\$50 000	Reference	Reference	Reference	Reference
Clinical specialty				
Other	0.64 (0.21–2.0)	0.31 (0.092–0.96)*	0.57 (0.16–2.0)	0.50 (0.15–1.6)
Surgery	0.54 (0.13–2.3)	3.5 (0.51–72.0)	1.8 (0.37–9.7)	2.4 (0.59–11.0)
Internal medicine/paediatrics/neurology/pathology	Reference	Reference	Reference	Reference
Completion of a clinical fellowship				
Yes	1.0 (0.35–2.9)	2.0 (0.66–6.1)	1.5 (0.46–5.0)	0.61 (0.22–1.7)
No	Reference	Reference	Reference	Reference
Completion of a research fellowship				
Yes	3.3 (1.1–12.0)*	5.1 (1.4–24.0)*	4.3 (1.3–16.0)*	4.6 (1.6–14.0)†
No	Reference	Reference	Reference	Reference
Completion of a Masters degree prior to MD/PhD				
Yes	0.21 (0.05–0.78)*	0.69 (0.19–2.7)	0.17 (0.024–0.85)*	0.73 (0.19–2.5)
No	Reference	Reference	Reference	Reference
Time spent in an MD/PhD programme, years	1.6 (1.1–2.5)*	1.3 (0.87–2.0)	1.4 (0.9–2.1)	1.1 (0.73–1.6)
First-authored manuscripts during MD/PhD training, n				
≥4	0.79 (0.28–2.2)	1.4 (0.48–4.1)	3.7 (1.1–14.0)*	1.8 (0.66–5.0)
0–3	Reference	Reference	Reference	Reference
Co-authored manuscripts during MD/PhD training, n				
≥7	2.7 (0.91–8.7)	1.4 (0.47–4.4)	1.5 (0.47–5.0)	1.1 (0.41–3.1)
0–6	Reference	Reference	Reference	Reference

Values in bold met criteria for statistical significance.

CI = confidence interval; PI = principal investigator.

* p < 0.05.

† p < 0.01.

Multivariable regression

When data were adjusted for gender and time since graduation, length of time spent in an MD/PhD programme was positively associated with the

odds of having protected research time in the current appointment. Further, MD/PhD graduates who had published four or more first-authored manuscripts during their training had significantly greater odds of having been the PI on a recent

funded project, and graduates who had published seven or more co-authored manuscripts during their training dedicated an average of 15% more time to research in their current position. Finally, MD/PhD graduates who had completed a research fellowship had significantly greater odds of sustained research involvement as indicated by all four binary outcomes, and dedicated a significantly greater percentage of time to research in their current appointment (Tables 2 and 3).

Conversely, the completion of a Masters degree prior to entering the MD/PhD programme decreased the odds of having protected research time in the current appointment and of having acted as PI on a funded project during the previous 36 months. Additionally, completion of training in a clinical specialty other than internal medicine, paediatrics, neurology, pathology and the surgical specialties was associated with decreased odds of planned substantial involvement in future research (Table 2). There was no significant relationship between completion of a clinical fellowship and any indicator of sustained research involvement.

DISCUSSION

MD/PhD programmes collectively represent a significant investment of funding. Yet, studies have consistently found that 14–16% of graduates do not pursue careers in research.^{1,9,10} Our findings that debt of greater than CAD\$50 000 at completion of training, and training in a clinical specialty other than internal medicine, paediatrics, pathology, neurology and a surgical specialty are each negatively associated with at least one indicator of continued research activity are consistent with previous observations.^{9,11} These four specialties have historically represented the most common choices of residency programmes among Canadian and US graduates. Brass et al.⁹ suggest that these programmes are popular among MD/PhD graduates because these specialties are more likely to provide a protected environment for career development in a traditional physician-scientist role. Despite the approximately equal proportions of male and female applicants admitted to Canadian medical schools, only 13 of 70 (19%) survey respondents who had completed all training were female. The negative association between female gender and sustained research involvement is consistent with previous findings

Table 3 Results from multivariable regression models of the relationships between percentage of time dedicated to research in the current position and independent variables, adjusted for gender and time since graduation (years), for Canadian MD/PhD programme graduates who had completed all training (n = 70)

	Percentage of time dedicated to research in current position Adjusted beta (95% CI)
Gender	
Male	19.7 (3.3–36.2)*
Female	Reference
Debt at completion of training	
≥CAD\$50 000	–8.0 (–21.9 to –5.9)
<CAD\$50 000	Reference
Clinical specialty	
Other	–12.0 (–25.7 to 1.78)
Surgery	0.6 (–17.8 to 19.0)
Internal medicine/ paediatrics/ neurology/pathology	Reference
Completion of a clinical fellowship	
Yes	2.8 (–10.3 to 15.9)
No	Reference
Completion of a research fellowship	
Yes	19.0 (6.8–32.0)†
No	Reference
Completion of a Masters degree prior to MD/PhD	
Yes	–8.7 (–25.4 to 8.1)
No	Reference
Time spent in an MD/PhD programme, years	1.9 (–2.9 to 6.7)
First-authored manuscripts published during MD/PhD training, n	
≥4	12.5 (–0.1 to 25.2)
0–3	Reference
Co-authored manuscripts published during MD/PhD training, n	
≥7	14.9 (2.4–27.4)
0–6	Reference

CI = confidence interval. Values in bold met criteria for statistical significance.
* p < 0.05.
† p < 0.01.

that the proportion of women in academic careers decreased with increasing university rank within Canada²¹ and highlights the importance of policies that support the participation of women

in the physician-scientist workforce. However, the small number of female MD/PhD programme graduates limits the interpretation of these findings.

The unique outcomes captured by our survey data provide a basis for the use of new predictors of sustained research involvement following postgraduate training. Our analysis suggests that research productivity during MD/PhD training is predictive of sustained involvement in research, particularly with respect to first-authored and co-authored manuscripts. Unfortunately, data concerning publications arising from postdoctoral research training or as an independent investigator were not collected. Our data additionally indicate that extending the duration of the thesis is associated with an increased likelihood of securing protected research time following postgraduate training. Our findings raise the possibility that a 7-year integrated MD/PhD programme does not include sufficient time in graduate studies (typically, 3 years) for trainees to become competitive for research-intensive appointments following graduation. However, this possibility should be balanced against the fact that integrated MD/PhD programmes already require considerable time to complete. Further integration between clinical and research curricula in MD/PhD programmes may reduce the time required to complete an MD/PhD, perhaps to approximate the 7 years characteristic of some existing programmes. It should also be noted that length of time spent in an MD/PhD programme was not associated with any of the other four indicators of sustained research involvement. By contrast, the significant association between completion of a research fellowship and all indicators of continued research activity suggests that participation in a postdoctoral research programme is a highly valuable experience for physician-scientists. In view of the long training time of physician-scientists (median: 13.5 years¹), our findings highlight the importance of undertaking research training, such as that provided within the Royal College of Physicians and Surgeons of Canada Clinician Investigator Program within Canada or residencies that provide one or more years of integrated research training in the USA, in concert with clinical residency programmes.

Surprisingly, completion of a Masters degree was negatively associated with protected research time in the current appointment, and having served as PI on a recent funded project. To our knowledge, this finding has not been reported in previous

studies. Trainees who complete Masters degrees may not have sufficiently strong academic or research records to gain admission to MD/PhD programmes immediately following undergraduate studies. Alternatively, trainees who have completed both a Master of Science (MSc) and a combined MD/PhD may be less likely to complete further research training. Interpretation of this finding is limited by the small number of respondents who had completed Masters degrees ($n = 13$), and the fact that all respondents had completed MSc degrees, as opposed to other types of Masters degree. Further study is required to determine if these results are reproducible and to establish whether different types of Masters degree are differentially associated with sustained research involvement.

Our national analysis of research outcomes among physician-scientist trainees yields some methodological insights for other programme evaluators. Firstly, in the absence of a coordinated system for tracking MD/PhD programme enrollees and graduates, current contact information and in some cases even the names of graduates could not be identified. Future evaluators would benefit from such a system, as is required of US programmes receiving funding from the NIGMS.⁹ Secondly, different measures of sustained research involvement are correlated, but capture distinct aspects of a physician-scientist career. Investigators who wish to evaluate physician-scientist training should carefully consider the elements of career success they intend to measure while designing their analysis.

Limitations

The most significant limitation of the present study is its small sample size: only 70 individuals who had graduated from Canadian combined MD/PhD programmes and completed all physician-scientist training were included in the study population. However, the sample size primarily reflects the small number of Canadian MD/PhD graduates, particularly when alumni who are still completing postgraduate training are excluded. In general, we are more confident that our independent variables are truly associated with sustained research involvement when they are independently associated with more than one outcome. The relatively high response rate to the national survey among participating programmes (75% among all graduates, 77% among contacted graduates) mitigates the impact of non-response bias on our results. Graduates of one Canadian MD/PhD programme

(University of Calgary) were excluded from the survey on the grounds that this institution's Leaders in Medicine programme includes individuals who have completed a PhD prior to entering medical school and hence it cannot be compared with the combined MD/PhD programme as it is delivered across the rest of Canada. Our findings may not be generalisable to individuals who have completed MD and PhD degrees sequentially.

CONCLUSIONS

Most Canadian MD/PhD programme graduates remain substantially involved in research on the basis of at least one outcome. However, this involvement often does not correspond to traditional descriptors of physician-scientist careers: for example, only 43% of graduates appointed at the level of assistant professor or higher dedicated the majority of their time to research in their current appointment. Our analysis leads to recommendations to minimise attrition in the physician-scientist training pipeline. By promoting excellent outcomes among trainees, including first-author publications as well as collaborations, MD/PhD programmes may be able to increase the likelihood that these trainees will successfully establish independent research programmes. With respect to MD/PhD programme structure, the provision of more dedicated research time than is offered by most 7-year programmes may be required for trainees to become competitive for funding as early-career investigators. At the same time, caution must be taken to prevent 'training fatigue' in an already long career development pipeline. For their part, trainees who wish to maintain substantial involvement in research should seek out opportunities to integrate research training into their residencies, as offered by the Clinician Investigator Program within Canada or research years at some US residency programmes. Both MD/PhD programmes and policymakers should focus on establishing and securing stable sources of funding for trainees in order to minimise debt and hence to prevent the loss of investments in physician-scientist training. Finally, further study is warranted to identify appropriate interventions that can specifically address attrition among female physician-scientists.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Appendix S1. Survey administered to alumni of eight Canadian MD/PhD programmes.

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