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Academic Productivity Differences by Gender and Child Age in Science, Technology, Engineering, Mathematics, and Medicine Faculty During the COVID-19 Pandemic

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Abstract

Background: Due to the COVID-19 pandemic, most faculty in science, technology, engineering, mathematics, and medicine (STEMM) began working from home, including many who were simultaneously caring for children. The objective was to assess associations of gender and parental status with self-reported academic productivity before (*i.e.*, mid-January to mid-March 2020) and during the pandemic (*i.e.*, mid-March to mid-May 2020).
Materials and Methods: STEMM faculty in the United States ($N = 284$, 67.6% women, 57.0% with children younger than the age of 18 years living at home) completed a survey about the number of hours worked and the frequency of academic productivity activities.
Results: There was no significant difference in the hours worked per week by gender (men, *M* [standard deviation, SD] = 45.8 [16.7], women = 43.1 [16.3]). Faculty with 0–5-year-old children reported significantly fewer work hours (33.7 [13.9]) compared to all other groups (No children = 49.2 [14.9], 6–11 years old = 48.3 [13.9], and 12–17 years old = 49.5 [13.9], $p < 0.0001$). Women's self-reported first/corresponding author's and coauthor's article submissions decreased significantly between the two time periods; men's productivity metrics did not change. Faculty with 0–5-year-old children completed significantly fewer peer review assignments, attended fewer funding panel meetings, and submitted fewer first authors' articles during the pandemic compared to the previous period. Those with children aged 6 years or older at home or without children at home reported significant increases or stable productivity.
Conclusions: Overall, significant disparities were observed in academic productivity by gender and child age during the pandemic and if confirmed by further research, should be considered by academic institutions and funding agencies when making decisions regarding funding and hiring as well as promotion and tenure.

Keywords: gender in STEM, work-family balance, science policy

Introduction

As of June 2020, the novel coronavirus-2019 (COVID-19) has infected over 2 million individuals in the United States, with over 110,000 associated deaths.[1] Due to ''stay-at-home'' orders from 43 states, a majority of faculty in science, technology, engineering, mathematics, and medicine (STEMM) were required to work from home. Given that 90% of working Americans have at least one child during their working years,[2] many STEMM faculty are without child care due to the closing of school and child care facilities and distancing from babysitters, neighbors, and extended family who might otherwise be sources of support.

Even before the pandemic, household work and care work were not equally distributed by gender, with married women spending almost twice as much time on domestic and child care responsibilities compared to men.[3] Even among high-achieving STEMM faculty, women carry a disproportionate load of household and child care duties.[4] With school and child care closures, many STEMM faculty are required to manage their laboratories (including transitioning research using remote methodologies), transfer courses to online platforms, and continue academic productivity, while simultaneously caring for and homeschooling their children. Productivity in academia is often characterized by submitting grants and articles, key currencies for success in academia, as well as other activities that build national prestige, such as peer review and serving on funding panels, which are essential for promotion and tenure. Without child care available, it could become challenging for STEMM faculty to continue typical levels of academic

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productivity.[5] This may have consequences for retention of STEMM faculty, as children have been identified as one reason people leave the STEMM fields. One study documented that 43% of women and 23% of men left full-time STEMM employment after having their first child, rates that are significantly higher than in faculty without children.[6] COVID-19 and the ramifications of school/child care closures have the potential to magnify gender differences in home and child care.

Gender inequities have already long been observed in STEMM fields,[4–10] but may be particularly acute during the COVID-19 pandemic. A virtual ethnographic study in Italian working mothers in COVID-19 lockdown suggests that women are performing the majority of household and care duties.[11] Pandemic-related productivity differences by gender are slowly emerging, with women submitting fewer preprints compared to men[12,13] and appearing to constitute a lower proportion of first authors of medical research on COVID itself than expected.[14] Taken together, the existing gender inequities in STEMM and challenges resulting from lack of child care options during COVID-19 may compound and directly impact academic productivity, with long-term ramifications in retention, promotion, and tenure of women and parents following the pandemic. Research characterizing the effects of COVID-19 on measures of academic productivity by gender and child age is necessary to highlight potential unintended consequences of ''stay-at-home'' orders and inform institutional policies and procedures following COVID-19, which could support gender equity and equity associated with other demographic characteristics (*e.g.*, race) and expand efforts to retain a diverse workforce. Thus, the objective of this study is to assess the relationships between gender and child age on self-reported academic productivity before and during the COVID-19 pandemic. We hypothesize that women and individuals with children at home will have significantly lower productivity during COVID-19 related ''stay-at-home'' orders relative to men and faculty without children at home.

Materials and Methods

Participants are STEMM faculty at universities/colleges in the United States who completed the survey. We designed the survey after reviewing the relevant literature and tenure and promotion metrics from universities and colleges in the United States to identify cited indices of productivity and academic success. Respondents were recruited using snowball sampling through emails to likely eligible individuals both within and outside of the authors' institutions, postings to department and university listservs, and social media postings on the personal Facebook and Twitter pages of the authors as well as Facebook groups for faculty. The study was determined to be exempt by the University of Tennessee Health Science Center's Institutional Review Board, and respondents provided informed consent.

The survey assessed demographic characteristics (*i.e.*, gender, race, ethnicity, age, marital status, and age of youngest child living at home) and the nature of current faculty position (*i.e.*, tenure status, rank, full-time/part-time status, and field of study). In addition, faculty reported the number of hours they had worked in the mid-March to mid-May period (*i.e.*, the first 2 months of the ''stay-at-home'' orders). Furthermore, we inquired about the number of times they had done the following tasks during the prepandemic period of mid-January to mid-March 2020 (*i.e.*, the 2 months before ''stay-at-home'' orders) and during the pandemic period of mid-March to mid-May 2020: (i) serve as a peer reviewer on a journal article; (ii) serve on a review panel for funding; (iii) submit a new article as first/corresponding author (not counting resubmitting the same article to a different journal); (iv) submit a new article as senior author (*i.e.*, indicated as second or last author depending on the field); (v) submit a new article as coauthor (not in the first or senior author position); and (vi) submit or resubmit a research grant. Finally, among faculty with children younger than 18 years of age at home, we assessed primary form of child care utilized (*i.e.*, provided by a child care center, relative, partner, babysitter, or self-provided child care) for the period from mid-March to mid-May; respondents answered the question, ''What has been your main form of child care in the past two months?'' We also assessed the proportion of child care (measured as a percent of time; 0%–100%) that the respondents were providing themselves; respondents answered the question, ''In the past two months, what proportion of the child care have you been providing?''

We examined overall productivity changes between the prepandemic period and pandemic period and compared respondents in productivity metrics by gender and by the age category of their youngest child living at home (younger than 18 years of age). We categorized the age of the youngest child into three categories, each spanning 6 years: (0–5 years old [*i.e.*, ''preschool'' children], 6–11 years old [primary school aged children], and 12–17 years old [middle/junior or high school-aged children]). (Those who had children older than the age of 18 years or children not living at home were categorized as not having children living at home.) The data, documentation, and code used in the analyses are available upon request to the first author.

Analysis

We described various characteristics of the sample using counts and percentages for categorical data and means and standard deviations (SDs) for continuous data. Independent *t*-test and one-way between-groups analysis of variance were conducted to explore the impact of respondent's gender and age of youngest child living at home on measures of academic productivity and work hours. *Post hoc* comparisons were conducted using the Scheffe test. We compared productivity metrics for the prepandemic period (*i.e.*, mid-January to mid-March of 2020) to the pandemic period (*i.e.*, mid-March to mid-May 2020) across the entire sample and stratified by respondent's gender and by age of their youngest child living at home (or not, if they did not have a child living at home) using means, SDs, and paired sample *t*-tests for continuous data. Due to small cell sizes, we did not examine outcomes for individuals whose gender identified as nonbinary, examine the interaction of respondent's gender and age category of youngest child, or examine interactions between gender and race/ethnicity. For statistical inference, we considered test statistics with *p*-values at or below 0.05 to be significant. Analyses were conducted using SPSS (version 26).

Results

The total sample comprised 284 individuals who completed the survey out of the 372 who started the survey (76.3%). Of the 284 included respondents, 192 (67.6%)

identified as women (Table 1), and 26 (9.6%) identified their ethnicity as Hispanic. The respondents identified as white (79.9%), Asian (9.2%), Black (2.8%), Native American (0.7%), Native Hawaiian or Pacific Islander (0.4%), or multiracial or another racial group (5.6%), and 1.4% did not report a racial identification. The mean respondent age was 42.1 years, and 86.6% were married or living with a partner. Tenure had been acquired in 38% of the sample, 37% were on the tenure track, and 25% were not on tenure track. The largest group of participants were in health sciences (43.7%). Overall, about half (57.0%) had children younger than the age of 18 years living at home. The majority were splitting time in child care with a partner or coparent (69.8%) or caring for children independently (14.8%; Table 2).

Full-time faculty (97.2% of the sample) reported working, on average, 44.1 (SD = 16.7) hours per week during the ''stay-at-home'' order. There was no significant difference in the number of hours reported worked by men (M [SD] = 45.8 [16.7]) and women (M [SD] = 43.1 [16.3], $p = 0.22$), who were working full-time. However, there was a significant difference in reported hours worked based on age of the youngest child. *Post hoc* comparisons using the Scheffe test indicated that parents whose youngest children who were 0–5 years old reported significantly fewer work hours per week (M [SD] = 33.7 [13.9]) compared to all of the other groups ($p < 0.0001$); there were no significant differences in mean hours worked between any of the other groups (No children at home: M [SD] = 49.2 [14.9], Youngest child 6–11 years old M [SD] = 48.3 [13.9], and Youngest child 12–17 years old M [SD] = 49.5 [13.9]). In addition, among those with children at home, women reported providing 77.6% (25.7) of the child care themselves, while men reported providing 61.3% (33.7) of the child care themselves ($p < 0.001$; Table 2).

There was an overall decrease in coauthored publications after the outbreak of the pandemic and implementation of social policies to address its containment; with an average of 0.9 (1.1) articles submitted per respondent in the 2-month period before the ''stay-at-home'' order, while an average of 0.7 (1.1) articles submitted per respondent in the first 2 months of the pandemic (Table 3). There were no significant differences in productivity metrics between the two time periods for men; women reported a significant decrease in first/corresponding author's submissions ($p = 0.04$), as well as a significant decrease in coauthor's article submissions ($p = 0.02$) between the two time periods (Table 3). There were no other significant differences in productivity measures for women between the two time periods.

When examining differences between the time periods for faculty with youngest children in the different categories, faculty with their youngest children in the 0–5-year-old group completed fewer peer review assignments ($p = 0.001$; Table 3) during the ''stay-at-home'' order than before. Those with children in the 0–5-year-age group also attended fewer funding panel meetings ($p = 0.03$) and submitted fewer new first author's articles ($p = 0.003$) during the ''stay-at-home'' order compared to the previous period. Faculty with youngest children in the 6–11-year-old group attended more funding panel meetings ($p = 0.002$) during the period of the ''stay-at-home'' order than beforehand. Among faculty with youngest children in the 12–17-year-old group, there were no significant changes in the productivity metrics reported. Among faculty with no children living at home, there was a

Table 1. Characteristics of Two Hundred Eighty-Four Respondents to a 2020 Survey of Science, Technology, Engineering, Mathematics, and Medicine Faculty in the United States

Tenure status [No. (%)]	
Tenure-track	105 (37.0%)
Tenured	108 (38.0%)
Nontenure track	71 (25.0%)
Rank (for those tenured or on the tenure-track, $N = 214$) [No. (%)]	
Assistant Professor	99 (46.3%)
Associate Professor	58 (27.1%)
Professor or Endowed/Distinguished Professor or similar	56 (26.1%)
Full-time position [No. (%)]	276 (97.2%)
Gender [No. (%)]	
Women	192 (67.6%)
Men	88 (31.0%)
Nonbinary	3 (1.1%)
Missing	1 (0.4%)
Race [No. (%)]	
White	227 (79.9%)
Asian	26 (9.2%)
Black/African American	8 (2.8%)
Native American	2 (0.7%)
Native Hawaiian or Pacific Islander	1 (0.4%)
Multiracial/other racial group	11 (5.6%)
Missing	4 (1.4%)
Hispanic [No. (%)]	26 (9.2%)
Age [M (SD)]	42.1 (9.6)
Field [No. (%)]	
Mathematics	9 (3.2%)
Physics	4 (1.4%)
Computer Science	3 (1.1%)
Engineering	22 (7.7%)
Chemistry	9 (3.2%)
Health Sciences	124 (43.7%)
Political Science	1 (0.4%)
Social Sciences	31 (10.9%)
Biology	30 (10.6%)
Medicine	27 (9.5%)
Other	13 (4.6%)
Missing	11 (3.9%)
Married/living with a partner [No. (%)]	246 (86.6%)
Age of youngest child living at home (younger than 18 years of age) [No. (%)]	
None	120 (42.3%)
0–5 Years of age	87 (30.6%)
6–11 Years of age	46 (16.2%)
12–17 Years of age	29 (10.2%)
Missing	2 (0.7%)
No. of courses transitioned to remote [No. (%)]	
0	95 (33.5%)
1	90 (31.7%)
2	44 (15.5%)
3	30 (10.6%)
4	6 (2.1%)
5	5 (1.8%)
Missing	14 (4.9%)

SD, standard deviation.

significant increase in submitted grants during the ''stay-at-home'' order ($p=0.02$) than the preceding period. There were no other significant differences in these productivity measures by age of youngest child living at home between the two time periods.

Discussion

In a sample of STEMM faculty diverse in terms of gender, tenure status, rank, and age of children at home, we assessed the relationships between gender and child care responsibilities on self-reported academic productivity before and during the first 2 months of the COVID-19 pandemic. Almost 6 out of 10 faculty had children younger than the age of 18 years at home. Reported changes in productivity before and during the first 2 months of the pandemic reflect that women may be submitting significantly fewer first/corresponding and coauthor's articles, but no other differences by gender were observed. Significant decreases in various productivity metrics were reported for individuals with children younger than the age of 6 years at home; meanwhile, those with children of 6 years or older at home or without children younger than the age of 18 years at home reported significant increases or stable productivity. Thus, women reported a significant decrease in one aspect of productivity (*i.e.*, article submissions) during the pandemic, whereas having very young children may be a salient risk for decreased productivity across multiple domains during the pandemic.

Overall, faculty reported working an average of 44 hours per week during the ''stay-at-home'' orders. Faculty without children and those whose youngest child was aged 6 years or older reported working nearly 50 hours per week. Typical work hours for full-time faculty have previously been reported at almost 54 hours per week,[15] suggesting that all faculty may have been working slightly less than normal during the first 2 months of the pandemic. This may be due, in part, to faculty previously reporting spending $\sim$25% of their time attending conferences, workshops, and receptions, traveling, and attending meetings,[16] all activities which may

Table 2. Characteristics of Faculty with Children Living at Home ($N=162$)

	No. (%)
No. of children at home	
1	62 (38.3)
2	78 (48.1)
3	16 (9.9)
4	4 (2.5)
Missing	2 (1.2)
Primary child care format during the stay at home order	
Child care center	2 (1.2)
Splitting time with a partner/coparent	113 (69.8)
Care by another relative	9 (5.6)
Care by a babysitter	8 (4.9)
Caring for children independently	24 (14.8)
Other	3 (1.9)
Missing	3 (1.9)
	M (SD)
Percent of time spent engaged in child care	
Women	77.6% (25.7)
Men	61.3% (33.7)

Table 3. Faculty Productivity Changes From the Two Month Period Before the COVID-19 Stay-At-Home Orders and the First Two Months of the Stay-At-Home Orders

	New first/corresponding author's articles submitted		*New senior author's articles submitted*		*Coauthor's articles submitted*		*Peer review of articles*		*Funding panel meetings attended*		*Grants submitted*	
	Prepandemic M (*SD*)	*Pandemic* M (*SD*)	*Prepandemic* M (*SD*)	*Pandemic* M (*SD*)	*Prepandemic* M (*SD*)	*Pandemic* M (*SD*)	*Prepandemic* M (*SD*)	*Pandemic* M (*SD*)	*Prepandemic* M (*SD*)	*Pandemic* M (*SD*)	*Prepandemic* M (*SD*)	*Pandemic M(SD)*
Overall	0.7 (0.9)	0.6 (1.0)	0.6 (0.9)	0.5 (1.0)	**0.9 (1.1)**	**0.7 (1.1)***	1.9 (1.8)	1.9 (2.2)	0.3 (0.6)	0.2 (0.5)	0.6 (0.9)	0.7 (1.2)
Gender												
Men	0.8 (1.1)	0.9 (0.1.3)	0.7 (1.0)	0.8 (1.2)	1.0 (1.1)	0.9 (1.4)	2.4 (2.1)	2.3 (2.4)	0.4 (0.8)	0.4 (0.6)	0.6 (1.0)	0.7 (1.1)
Women	**0.6 (0.8)**	**0.5 (0.8)***	0.5 (0.9)	0.4 (0.8)	**0.9 (1.2)**	**0.6 (0.9)***	1.6 (1.6)	1.7 (2.1)	0.2 (0.4)	0.2 (0.4)	0.5 (0.8)	0.7 (1.2)
Age of youngest child living at home												
None	0.6 (0.8)	0.6 (1.0)	0.3 (0.8)	0.4 (0.8)	0.8 (1.2)	0.6 (0.9)	1.5 (1.7)	1.8 (2.2)	0.3 (0.5)	0.2 (0.5)	**0.5 (0.8)***	**0.8 (1.2)***
0–5 Years	**0.9 (1.1)**	**0.5 (1.0)****	0.6 (0.4)	0.4 (0.9)	1.0 (0.8)	0.8 (1.1)	**2.3 (1.7)**	**1.6 (1.7)****	**0.3 (0.6)**	**0.1 (0.3)***	0.7 (0.9)	0.5 (1.0)
6–11 Years	0.6 (0.8)	0.6 (0.9)	1.2 (1.1)	1.0 (1.3)	1.0 (1.2)	0.7 (1.5)	2.4 (2.0)	2.9 (3.1)	**0.3 (0.5)**	**0.7 (0.7)****	0.7 (1.0)	1.1 (1.5)
12–17 Years	0.7 (0.9)	0.6 (1.1)	0.9 (1.2)	0.9 (1.2)	0.9 (1.2)	0.9 (1.5)	1.2 (1.3)	1.5 (1.6)	0.5 (0.9)	0.3 (0.7)	0.5 (0.8)	0.7 (0.7)

Prepandemic refers to mid-January to mid-March period 2020 (*i.e.*, the 2 months before ''stay-at-home'' orders), Pandemic refers to mid-March to mid-May period 2020.
Significant change over the time period in paired *t*-test bolded, *$p<0.05$ and **$p<0.01$.

have been decreased during the pandemic. Faculty may also have been distracted by pandemic-related news, increased self-care needs without usual sources of personal assistance available, or other challenges to concentration in this unusually stressful context. We observed no differences in hours worked by gender, but we found a difference by the age of the youngest child: parents with very young children (ages 0–5) at home reported working nearly 15 fewer hours per week compared to their counterparts without children at home or those whose youngest child was at least school-aged, consistent with other recent research.[17] These findings may reflect the heightened needs of young children for constant physical supervision and attention, which can be substantial even when shared with a coparent, as was the experience reported by most of our participants.

The decrease in working hours among parents with very young children may explain the decreased reported productivity among this group (*i.e.*, a statistically significant decrease in first/corresponding author's publications, peer review of articles, and a decrease in funding panel meetings attended). Parents with very young children also reported a decrease in senior- and coauthor's articles submitted and grants submitted relative to prepandemic productivity, but these results were not statistically significant. It is possible that the reduction in working hours resulted in a reduction in publishing because these activities may be perceived as optional (particularly among those who are tenured) or not time-sensitive, unlike other faculty activities such as transitioning course instruction to remote technologies.

Given that prime reproductive years generally overlap with the early career stage of scientific careers,[4] STEMM faculty with very young children are more likely to be early stage investigators without tenure and more vulnerable to attrition from the academic pipeline. Consistent with work before COVID-19[3,4,8] and emerging data from the COVID-19 pandemic in Italy,[11] women in our study reported providing significantly more of the child care than men. Thus, the impact of child care responsibilities with very young children may fall disproportionately on early-career women. This highlights the need for special consideration of parents with very young children, particularly women, in job applications, grant funding, and consideration in tenure and promotion. While the National Institutes of Health have approved no-cost extensions of currently funded grants for up to 1 year and additional time to submit grant applications to account for lost time due to the pandemic,[18] the current study findings highlight the need to identify other policies and procedures that academic institutions could implement to further support early career investigators with young children with reduced productivity resulting from COVID-19.[19,20]

Our data also indicate that the COVID-19 pandemic may be exacerbating preexisting gender inequities in STEMM fields.[4–10] Despite a slight observed increase in first- and coauthored articles by women in recent decades, last (senior) authorship and citation of publications remain consistently lower for women,[21] with publications being perceived to be of lesser quality with women as first or senior authors compared with men.[22] In the current study, women indicated a statistically significant drop in first- and coauthor's article submissions, consistent with early estimates of COVID-19 demonstrating a downward trend among women compared to men in article submissions.[12–14] Publications are essential for job applications, tenure, and promotion, as well as demonstrating competence as a researcher in grant applications. Publications may be particularly important for women, since one study found that women who were applying for a postdoctoral research fellowship needed more than twice as many publications to receive the same competence score as men who applied.[23] Furthermore, a core aspect of review on federal grants is an evaluation of the investigator, who must demonstrate publishing articles in prominent journals; one study found that gender disparities in funding are attributable to less favorable assessments of women as principal investigators, not of the quality of their proposed research.[24] Women are also less likely to get their grant renewed,[25] potentially due, in part, to gender bias observed in National Institutes of Health reviews.[26] These factors put women at a significant disadvantage in achieving academic success compared with their male counterparts. Although we were unable to assess gender by age of the youngest child interactions, it is possible that reductions in productivity were compounded for women with very young children, given previous data on child care responsibilities falling primarily on faculty women pre-COVID19[4] and during COVID-19 lockdowns in Italy.[11]

Strengths of this study included surveying faculty during COVID-19 ''stay-at-home'' orders and a diverse participant pool in terms of gender, age of children at home, tenure status, and rank. Limitations include insufficient sample to conduct analyses by race and ethnicity, which are likely important factors, given the disproportionate impact of COVID-19 morbidity and mortality in Black, Native American, and Hispanic populations[27] as well as inequities specific to Black, Native American, and Hispanic faculty.[28,29] Since the sample was primarily white, female, and faculty in the Health Sciences, it will be important to replicate these findings in a sample that is more diverse in gender, race, ethnicity, and area of study. In addition, the data are limited by the self-report of productivity measures and the cross-sectional nature of our study, which precludes the ability to analyze temporal relationships. We are unable to calculate a formal survey response rate, and there may be some selection bias related to the recruitment approach, especially since the respondents' demographic characteristics, including gender, do not reflect the overall population of STEMM faculty; however, we did not introduce bias by articulating our hypotheses when inviting faculty. A larger study would be necessary to confirm these findings, to disentangle the relationship between gender and having young children at home, and to evaluate interactions between child age and gender in greater depth; nevertheless, the findings of the present study are compelling in that they suggest that not only are parents of young children reporting diminished productivity but also women are reporting greater proportions of child care provision compared with men, suggesting that the adverse impact of the pandemic may affect women with young children even more than men.

Conclusions

The majority of STEMM faculty in this diverse sample from the United States reported maintaining similar working hours to that of their prepandemic state, with the notable exception of parents of very young children (ages 0–5), who

reported working ~15 hours less per week than counterparts without children at home or whose youngest child was aged 6 years or older. Those with very young children reported a significant decrease in academic productivity during the pandemic when compared to their productivity 2 months before the pandemic. Women reported providing a higher proportion of child care themselves and also reported a significant decrease in first and coauthor's article submissions, whereas no significant differences in productivity were reported by men. STEMM faculty with no child living at home younger than the age of 18 reported an increase in productivity related to grant submissions. Overall, significant disparities were observed in academic productivity by gender and child age during COVID-19 ''stay-at-home'' orders and, if confirmed by further research, should be considered by academic institutions and funding agencies when making decisions regarding funding, hiring, promotion, and tenure. It may be important for academic institutions and granting agencies to provide dedicated resources for early career faculty, particularly women and those with very young children, to attenuate the negative effects of academic productivity resulting from the COVID-19 pandemic. Finally, it will be important for future research to examine the intersectionality of gender, race/ethnicity, and child care responsibilities, since race and ethnicity are often also important factors that affect individuals' lived experiences, vulnerabilities, and career outcomes.

Authors Contributions

R.A.K. and M.I.C. designed and conceived of the work and drafted the article. R.A.K. acquired and analyzed the data. All authors interpreted the data, revised the draft critically for important intellectual content, and approved the final version to be published.

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