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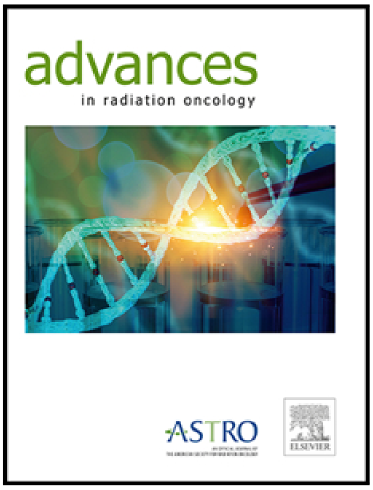

Diversity and Professional Advancement in Medical Physics

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Diversity and Professional Advancement in Medical Physics

Diversity in Medical Physics

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Conflict of Interest Statement:
BW has received a grant from the Australian National Health and Medical Research Council, is a shareholder of 4D Medical, was granted patent #US11105874B2, and is an AAPM committee member. JPL is a board member of AAPM. MS is an employee of Purdue University and is provided therapeutic agents for research study from Imagion Biosystems. KCP has received grants from Michigan Medicine and University of Michigan, related to the current work. The remaining authors report no conflicts of interest.

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Data Sharing Statement:
Data underlying this study include AAPM membership records, AAPM committee rosters, AAPM awards rosters, AAPM member demographics data, AAPM Education and Research Fund Recipient records, the AAPM-NIH Research Database, and United States population demographics data. AAPM membership records, AAPM committee rosters, AAPM awards

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rosters, and AAPM member demographics data were provided to the authors by AAPM; however, the authors do not own these data and are therefore unable to share them. AAPM Education and Research Fund Recipient records were made publicly available by AAPM and are available at: https://gaf.aapm.org/education/edfund.php. The AAPM-NIH Research Database is available to AAPM members upon request. United States population demographics data are publicly available at: https://data.census.gov/cedsci/.

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Abstract

Purpose: While disparities in the inclusion and advancement of women and minorities in science, technology, engineering, mathematics, and medical fields have been well-documented, less work has focused on medical physics specifically. In this study, we evaluate historical and current diversity within the medical physics workforce, in cohorts representative of professional advancement in the field, and within NIH-funded medical physics research activities.

Methods and Materials: The 2020 AAPM membership was queried as surrogate for the medical physics workforce. Select subsets of the AAPM membership were queried as surrogate for ȯprofessional advancementȯ(PA) and ȯearly-career professional advancementȯ(ECPA) in medical physics. Self-reported AAPM-member demographics data representative of study analysis groups were identified and analyzed. Demographic characteristics of the 2020 AAPM membership were compared to those of the PA and ECPA cohorts and U.S. population. The AAPM-NIH Research Database

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was appended with principal investigator (PI) demographics data and analyzed to evaluate trends in grant allocation by PI demographic characteristics.

Results: Women, Hispanic/Latinx/Spanish individuals, and individuals reporting a race other than óWhiteô or óAsianô alone comprised 50.8%, 18.7%, and 32.4% of the U.S. population, respectively, but only 23.9%, 9.1%, and 7.9% of the 2020 AAPM membership, respectively. In general, representation of women and minorities was further decreased in the PA cohort; however, significantly higher proportions of women ($p<0.001$) and Hispanic/Latinx/Spanish members ($p<0.05$) were observed in the ECPA cohort than the 2020 AAPM membership. Analysis of historical data revealed modest increases in diversity within the AAPM membership since 2002. Across NIH grants awarded to AAPM members between 1985-2020, only 9.4%, 5.3%, and 1.7% were awarded to women, Hispanic/Latinx/Spanish, and non-White, non-Asian PIs, respectively.

Conclusions: Diversity within medical physics is limited. Proactive policy should be implemented to ensure diverse, equitable, and inclusive representation within research activities, roles representative of professional advancement, and the profession at large.

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Introduction

Limited diversity in science, technology, engineering, mathematics, and medicine (STEMM) is a long-standing issue [1, 2]. Despite improvements in the inclusion of women and underrepresented minorities[1] at the undergraduate level [3], disparities persist in higher educational attainment [3, 4] and in activities classically representative of professional advancement, including scientific authorship [5] and amongst award and grant recipients [6-8]. Within academia, diversity tends to be more limited at the faculty level than amongst students, a trend that is exacerbated with increasing academic rank [3, 4, 9]. Collectively, these findings reveal a progressive decline in the representation of women and minorities in roles associated with increased seniority, specialization, or qualification—a ‘leaky pipeline’—through which there is a disproportionate loss of diversity along academic and career trajectories [see, e.g., 10-12]. Rather than

[1] In the context of STEMM higher education and workforce, ‘underrepresented minorities’ refers to individuals reporting Black or African American race, American Indian or Alaska Native race, or Hispanic or Latino ethnicity [3].

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representing a lack of talent, ability, or motivation amongst those exiting the pipeline, “pipeline leaks” have been attributed to a number of interrelated, systemic factors, including limited networking and mentorship opportunities, social isolation within the workplace, disproportionate service and administrative burdens, work-life integration challenges, implicit bias, and experiences of harassment and discrimination, amongst others [10-13]. Fortunately, improved understanding of these issues has led to development of ameliorating interventions and avenues for support within various fields [see, e.g., 11, 12, 14].

While work regarding diversity and professional advancement in medical physics is limited, existing scholarship suggests similar issues within the field. Recent analysis of the historical and current American Association of Physicists in Medicine (AAPM) membership revealed that women have remained underrepresented for over five decades, at maximum comprising 23.3% of AAPM members in 2019 [15]. Additionally, women were found to be underrepresented in a variety of clinical and AAPM leadership positions, including as CAMPEP program directors and AAPM council chairs, within AAPM executive committee roles, and as award recipients. Development and analysis of the AAPM-NIH Research Database has also revealed gender disparities in the allocation of research funding [16]. Amongst AAPM members, men are more than twice as likely to hold NIH funding than are women [16], and, relative to representation in the AAPM membership, a consistently lower proportion of women held NIH funding than did men for all years 2002-2019 [17]. Collectively, this literature reveals that women are not only underrepresented in medical physics in general, but they are even less likely to

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hold roles or distinctions classically representative of professional advancement in the field.

Improvements in the recruitment, retention and career advancement of women and minority medical physicists would benefit the entire medical physics workforce, as a diverse and inclusive climate begets enhancements in innovation, productivity, and morale [18, 19]. Furthermore, increased workforce diversity may yield improvements in both public health and individual patient experiences. As medical providers, minority physicians disproportionately care for patients of medically underserved populations, including low income, minority, and Medicaid patients [20]. Additionally, racial concordance between patients and medical providers may be associated with increased patient satisfaction and cultural competence, longer encounters, and adherence to treatment plans [21-23]. Recent work has called attention to the particularly important role of a diverse oncology workforce in addressing racial disparities in cancer outcomes [24]. Given that, in 2019, 78% of PhD, board-certified medical physicists reported their role to be ñPrimarily Clinicalò[25], efforts to increase diversity in medical physics stand to produce meaningful improvements in patient care and outcomes.

To our knowledge, there has not been a comprehensive, quantitative study of historical and current diversity in the medical physics workforce, leadership pools, and research activities that includes analysis of race and ethnicity in addition to gender, nor which evaluates diversity in roles associated with early-career professional advancement. In this study, we therefore seek to analyze gender, racial, and ethnic diversity within the medical physics workforce and in cohorts representative of professional advancement in the field, including those representative of early-career professional advancement.

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Additionally, we use the AAPM-NIH Research Database [16] to examine trends in medical physics grant funding by principal investigator (PI) demographic characteristics. This work will provide meaningful context to support the development of actionable policy that ensures diversity and equitable opportunity for professional advancement within medical physics.

Methods

The 2020 AAPM membership was queried as surrogate for the current medical physics workforce, while select subsets of the AAPM membership representing career advancement and leadership were queried as surrogates for óprofessional advancementô(PA) and óearly-career professional advancementô(ECPA) in the field. The PA cohort included CAMPEP program directors, NIH grant recipients, and AAPM committee members, committee chairs, and award recipients. The ECPA cohort was comprised of two subgroups, óearly-career leadershipôand óearly-career research leadershipô Inclusion criteria for study analysis groups and subgroups are summarized in Table 1. Active AAPM membership in 2020 was added to the inclusion criteria for subgroups without criteria that otherwise ensured recent involvement in medical physics-related professional activities. Awards associated with the óAAPM award recipientsôsubgroup are available in Supplementary File A.

Historical membership, committee, and awards records provided by AAPM were used to identify AAPM members, committee members and chairs, and award recipients, respectively. NIH grant recipients, CAMPEP program directors, and AAPM Research Seed Grant recipients were identified through the AAPM-NIH Research Database [16],

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the CAMPEP website [26], and publicly available AAPM Education and Research Fund Recipients data [27], respectively.

Voluntary, self-reported demographics data for current and former AAPM members were provided by AAPM. Demographics data were recoded for clarity and, for race data, consistency with U.S. Census data [28]. A detailed data recoding schema is available in Supplementary File B. U.S. population race and ethnicity demographics data were obtained from the 2020 U.S. Decennial Census [29, 30]. U.S. population sex demographics data were obtained from the 2019 American Community Survey [31].

AAPM-member demographics data representative of the 2020 AAPM membership, PA cohort, and ECPA cohort were identified through a series of data processing steps (Figure 1). Number and percentage of members by demographic characteristic were calculated for each study analysis group. "Not Reported or Unavailable" demographics data were excluded from calculations of percentages. To evaluate historical trends in membership demographics, the process was repeated for all years of available AAPM membership data, 2002-2020.

The AAPM-NIH Research Database was appended with AAPM demographics data by merging datasets on PI AAPM-member identifier number. PI race and ethnicity were identified using appended AAPM demographics data, while PI gender identity was identified using a pre-existing "Gender" data field from the AAPM-NIH Research Database. Number and percentage of grants awarded by PI demographic characteristic were calculated, once across all grant activity types and once for the subset of K- and F-grants only. For both calculations, grants awarded in all years represented in the dataset, 1985-2020, were pooled. Data were filtered to ensure that grants were counted

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only once regardless of years of funding. To investigate historical trends, calculations were repeated with grants stratified by first year of funding. Grants with ôNot Reported or Unavailableô demographics data were excluded from calculations of percentages.

Data processing and analysis were performed using Python version 3.7.4 (Python Software Foundation, https://www.python.org/) and Microsoft Excel.

Statistical Analysis. Statistical analysis was performed using SAS version 9.4 (SAS Institute Inc). Demographic characteristics of the 2020 AAPM membership were compared to those of the PA cohort, ECPA cohort, and U.S. population. The one-sample test for proportions was used to determine whether differences in percentages of members reporting a given demographic identity were statistically significant at the $p<0.05$ level of significance. The exact one-sample test for proportions was used when one-sample test assumptions were not met. Statistical analysis was not performed in cases where one or both comparison group(s) contained no members reporting a given demographic identity.

Results

Demographic characteristics of the 2020 AAPM membership, PA cohort, ECPA cohort, and U.S. population are summarized in Table 2. Granular demographic characteristics of PA and ECPA cohort subgroups are available in Supplementary File C. Notably, AAPM-member demographics data was limited, with gender identity, race, and ethnicity reported by 90.2%, 38.6%, and 28.2%, respectively, of members represented in the dataset overall.

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In general, diversity within medical physics study analysis groups was limited (Figure 2(a)), and women and minority groups were frequently underrepresented. Women were significantly underrepresented in the 2020 AAPM membership relative to the U.S. population ($p<0.001$) and comprised a minority (23.5%) of PA cohort members. Similarly, Hispanic/Latinx/Spanish members were underrepresented in the 2020 AAPM membership relative to the U.S. population ($p<0.001$) and comprised only 8.7% of PA cohort members. Interestingly, the ECPA cohort was more diverse by gender and ethnicity, comprised of significantly higher percentages of women ($p<0.001$) and Hispanic/Latinx/Spanish members ($p<0.05$) relative to the 2020 AAPM membership.

Racial diversity within all medical physics groups was highly limited. Despite comprising 32.4% of the U.S. population, racial groups other than óWhiteô or óAsianô alone collectively comprised only 7.9%, 7.0%, and 6.1% of the 2020 AAPM membership, PA cohort, and ECPA cohort, respectively. Black/African American members were significantly underrepresented in the 2020 AAPM membership relative to the U.S. population, as were American Indian/Alaska Native members and members reporting óSome Other Raceô or óTwo or More Racesô While Asian members were overrepresented in the 2020 AAPM membership relative to the U.S. population ($p<0.001$), they were underrepresented in the PA cohort relative to the 2020 AAPM membership ($p<0.01$); however, there was no significant difference between the proportion of Asian members in the ECPA cohort and the 2020 AAPM membership. Two-sided *P*-values for all statistical tests are available in Supplementary File D.

The proportions of women, Hispanic/Latinx/Spanish, and Asian members in the AAPM membership generally increased between 2002 and 2020, while proportions of men,

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"Early-Career Professional Advancement" Cohort	Early-Career Leadership	• Member of any "Professional Advancement" cohort subgroup • Age less than 40 as of 1/1/2020
	Early-Career Research Leadership	• Received NIH K- or F-grant funding, an AAPM Research Seed Grant, or an AAPM early career or junior investigator award between 2016-2020

Table 2. Demographic Characteristics of the U.S. Population, 2020 AAPM Membership, and Medical Physics 'Professional Advancement' and 'Early-Career Professional Advancement' Cohorts.

	U.S. Population	2020 AAPM Membership (N = 9450)	'Professional Advancement' Cohort (N = 2894)	'Early-Career Professional Advancement' Cohort (N = 703)
Gender Identity, N (%*)				
Man	161,588,973 (49.2)	6844 (76.1)	2189 (76.4)	430 (61.7)
Woman	166,650,550 (50.8)	2149 (23.9)	674 (23.5)	266 (38.2)
Gender Identity Minority		3 (<0.1)	1 (<0.1)	1 (0.1)
Not Reported or Unavailable		454	30	6
Race, N (%*)				
White alone	204,277,273 (61.6)	2611 (64.6)	935 (69.3)	268 (68.5)
Asian alone	19,886,049 (6.0)	1112 (27.5)	321 (23.8)	99 (25.3)
Black or African American alone	41,104,200 (12.4)	107 (2.6)	29 (2.1)	7 (1.8)
Native Hawaiian or Pacific Islander alone	689,966 (0.2)	6 (0.1)	3 (0.2)	0 (0.0)
American Indian or Alaska Native alone	3,727,135 (1.1)	7 (0.2)	2 (0.1)	2 (0.5)
Some Other Race alone	27,915,715 (8.4)	89 (2.2)	26 (1.9)	5 (1.3)
Two or More Races	33,848,943 (10.2)	110 (2.7)	34 (2.5)	10 (2.6)
Not Reported or Unavailable		5408	1544	312
Ethnicity, N (%*)				
Hispanic, Latinx, or Spanish	62,080,044 (18.7)	289 (9.1)	90 (8.7)	41 (12.2)
Not Hispanic, Latinx, or Spanish	269,369,237 (81.3)	2875 (90.9)	944 (91.3)	294 (87.8)
Not Reported or Unavailable		6286	1860	368

*Counts for "Not Reported or Unavailable" groups were excluded from calculation of percentages.
†U.S. population data by race and ethnicity obtained from the 2020 U.S. Decennial Census [28, 29]. U.S. population data by sex obtained from the 2019 American Community Survey [30].

Table 3. NIH Grants Awarded to AAPM Members by Grant Activity Type and Principal Investigator Demographic Characteristics, 1985-2020 Pooled.

	Total Grants: Any Activity Type	Total Grants: K- and F-Grants Only
Gender Identity, N (%*)		
Man	1537 (90.6)	35 (71.4)
Woman	159 (9.4)	14 (28.6)

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Gender Identity Minority	0 (0.0)	0 (0.0)
Not Reported or Unavailable	36	1
Race, N (%*)		
White alone	300 (62.2)	13 (76.5)
Asian alone	174 (36.1)	3 (17.6)
Black or African American alone	1 (0.2)	0 (0.0)
Native Hawaiian or Pacific Islander alone	1 (0.2)	0 (0.0)
American Indian or Alaska Native alone	0 (0.0)	0 (0.0)
Some Other Race alone	2 (0.4)	1 (5.9)
Two or More Races	4 (0.8)	0 (0.0)
Not Reported or Unavailable	1250	33
Ethnicity, N (%*)		
Hispanic, Latinx, or Spanish	21 (5.3)	6 (37.5)
Not Hispanic, Latinx, or Spanish	373 (94.7)	10 (62.5)
Not Reported or Unavailable	1338	34

*Counts for ôNot Reported or Unavailableö groups were excluded from calculation of percentages.

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