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Elijah Sterling March 23, 2022

A Decade of Demographic Reporting in Neuroimaging Studies

by

Elijah Sterling

Dr. Candace Fleischer
Advisor

Neuroscience & Behavioral Biology

Dr. Candace Fleischer

Advisor

Dr. Gillian Hue

Committee Member

Dr. Michael Borich

Committee Member

2022

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Elijah Sterling

Dr. Candace Fleischer

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An abstract of
a thesis submitted to the Faculty of Emory College of Arts and Sciences
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Abstract

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By Elijah Sterling

To ensure translation and generalizability of results from biomedical studies, it is imperative to include diverse subjects. Evidence suggests demographic traits such as race, sex, and ethnicity are associated with differential outcomes in patient populations. Previous studies have examined the state of diversity in multiple fields and observed biomedical studies underreport and underrepresent several demographic groups. We conducted a systematic review to provide quantitative data about the state of reporting and reported diversity in neuroimaging studies published between 2010-2020. The final data analysis was performed using 408 articles. While a majority of studies report sex (77%), a minority report race (10%) and ethnicity (4%). Among the reported diversity, we observed nearly equal representation of both biological sexes, as well as nearly equal representation of ethnicity (Hispanic and non-Hispanic). Across all articles reporting race, a majority of participants were White. Our data shows a lack of reporting and inclusion of several racial groups in neuroimaging studies. Future steps to increase diversity may include guidelines for publishers, researchers, and institutions that mandate transparent reporting of demographic information and mandated inclusion of underrepresented minority groups.

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This thesis is dedicated to everyone who has helped me accomplish this task. Special thanks to my thesis advisor, Dr. Candace Fleischer who was instrumental in my mentorship that enabled me to produce this piece of scientific literature. As well as special thanks to my committee members Dr. Gillian Hue and Dr. Michael Borich for graciously serving on my committee and providing me with valuable insight into the project and its direction throughout the process.

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Introduction

Health disparities, disease presentation, and patient outcomes can differ according to multiple factors such as race, sex, and ethnicity[1-3]. Race has been shown to correlate with disparities in the ability to access treatment for neurological conditions. In a study evaluating 307,675 traumatic brain injury (TBI) patients, multiple non-Caucasian racial groups were reported to be released to home care without medical assistance at higher rates than Caucasian TBI patients[4]. In a study that compared sex specific differences in patients with juvenile myoclonic epilepsy (JME) (765 total, 278 male and 487 female), females were reported to experience seizures at higher rates due to stress and visual stimuli[5]. The same study also reported certain epilepsy-invoking factors observed in both sexes only predicted drug resistance in females, such as stress and concentration[5].

The manifestation of neurological conditions can also vary between individuals and subsets of the population. Alzheimer's disease, for instance, has been reported to express differentially in females as compared to males, evidenced by greater neural connectivity in the brains of female patients with AD[2]. Disease manifestation can also differ according to race. In a population of 64 participants of both African American and Caucasian race, researchers compared alcohol use disorder through blood samples and reported three different amino acids were statistically higher in the Caucasian cohort when compared to the African American cohort[6]. While the literature suggests demographic traits can play a role in various neurological conditions, not every study reports demographics or includes study subjects that reflect the larger population.

Demographic reporting and diversity in biomedical research

Historical underrepresentation of minority and female participants is well documented in the literature and has resulted in clinical and biomedical best practices informed by conclusions made using a narrow subset of the population[7-9]. There is documented evidence for the trend of utilizing predominantly White and/or male populations in biomedical research. In 1986, the National Institutes of Health (NIH) announced a policy designed to increase the inclusion of women and minorities in clinical studies[10] _ENREF_10. Initial reports and testimony in front of the

General Accounting Office stated women and minorities had not been effectively integrated into clinical studies[10]. The NIH Revitalization Act of 1993 provided a set of guidelines for including women and minorities in research[11]. Since its implementation, however, a lack of diversity has persisted with respect to the ethnicity, race, and sex of human participants in clinical research[12,13].

In neuroscience, studies that report demographic characteristics are still the minority[14]. A recent review focusing on studies of cognition in humans observed out of a total of 208 studies, less than 15% reported race/ethnicity[14]. Furthermore, in clinical trials funded by the NIH National Cancer Institute between 1993-2013, less than 2% of studies reported demographics consistent with the requirements set forth by the NIH Revitalization Act[11]. Previous articles have evaluated underrepresentation according to race and ethnicity across several fields[12,15]. In a review of the race and ethnicity of participants included in an Alzheimer's disease trial, Raman et al. reported the majority of participants were Caucasian (86%) among a total population of 5,495 participants[16]. A review of clinical trials assessing topics related to neuro-oncology also reported across 662 studies from 2000-2019, 92% of participants were Caucasian[17]. Burchard et al. reported on studies examining pulmonary disease which also received NIH funding from 1993-2013 and observed 4% of studies included racial and ethnic minorities[12].

Data from the cancer genome atlas (TCGA) also demonstrates some racial groups are underrepresented in research[3]. In a study by Zhang et al., the reported demographics of patient data included in TCGA database across sixteen different types of cancer indicated a majority of the subject population was White for all cancers[3]. Additionally, out of 594 samples collected from patients with glioblastoma multiforme, 505 (85%) were collected from White individuals, 50 (8%) from Black individuals, and 13 (2%) from Asian individuals[3].

The literature suggests when studies report diversity of participants, the subjects are not demographically diverse[18]; however, attention should be paid to the limited rates of reporting as it is difficult to ascertain the true diversity of participants. A recent review focusing on autism spectrum disorders reported a minority of articles considered race and ethnicity as parameters[18]. Through the systematic review of 1,013 articles published from 1990-2017, 24.9% of the articles reported race and/or ethnicity[18]. Data showed the majority of participants across studies were

White (63.6%), with strikingly smaller percentages for other racial and ethnic groups, ranging from <0.1% for Native American participants to 9.4% for Hispanic participants[18].

While previous studies have reported on the lack of demographic diversity in other fields[3,9,13,15,18-21], our goal was to advance this effort by reporting on the rates of reporting and diversity of participants in neuroimaging studies. We performed a systematic review of human neuroimaging studies utilizing magnetic resonance imaging (MRI). MRI was the focus due to its documented rise in usage. A study consisting of 377,048 patients who underwent diagnostic testing reported MRI examinations occur at a rate of 72 per 1,000 individuals[22]. In addition, the increase in the number of large MR datasets suggest its increased usage as a research tool, and MR studies provide a convenient sampling of the neuroimaging field to assess the reported rates of race, sex, and ethnicity[22,23]. The initial hypothesis was the majority of studies that utilize MR as a neuroimaging technique do not report demographics of human subjects, and of the studies that do report demographics, a majority of the subjects will be male and/or White.

Methods

A systematic review was conducted using the PRISMA guidelines (http://www.prisma-statement.org/). Searches were conducted using the Web of Science™ search engine. Initial search criteria were article topic of "human brain MR", the paper was written in English, the document type was article, and the final version of the article was published between 2010-2020, inclusive. The term *human* was used to focus the scope of the initial results as the topic "brain MR" returned 15,583 results whereas "human brain MR" returned 3,458 results. The abbreviation MR was used rather than "magnetic resonance" as many MR journals do not require the full spelling of this acronym and this would likely result in exclusion of relevant articles.

Exclusion criteria were the article was not primary research (e.g., review, perspective), no human brain MR data were acquired in the study, the total number of participants was less than 10, data were acquired outside the United States, and the journal did not meet a quality control check. To determine the location of the study, multiple sources of information were utilized including imaging location/center, name of Institution Review Board, and affiliation of authors listed. Journal quality was assessed using the Think-Check-Submit method

(https://thinkchecksubmit.org). If two or more criteria could not be met, the article was excluded. Although a single article may have met multiple exclusion criteria, articles were excluded and tallied in the order shown in Figure 1.

Each manuscript meeting initial search criteria was reviewed by two independent researchers using the same protocol for data inclusion and exclusion (Figure 1). One primary researcher reviewed all articles and two secondary researchers independently reviewed a subset of all articles. A fourth researcher not involved in data collection compared the independent results for each manuscript to identify differences and confirm results. Discrepancies were resolved through an additional review of the article by the two initial researchers as well as the primary investigator to reach a unanimous decision.

If the article was included, descriptive data was recorded including the full citation, date accessed, search engine and terms used, journal name, whether the study was funded in part or whole by NIH (yes/no), whether the reported data comes from a database and if so which database, relevant information about the participants in the study (e.g., health status or diagnosis), and whether demographics were reported. If demographics were reported, demographic information was also collected including sex, race, and ethnicity of each participant, disease focus, and age range of participants.

For biological sex, the two categories reported in our analysis were male and female. If an article reported either sex or gender of participants, the reported number of participants were classified as male or female. Categories for race included American Indian or Alaska Native, Black or African American, Asian or Pacific Islander, White, more than one race, and other. The categories for ethnicity including Hispanic or Latino, Non-Hispanic or Non-Latino, and other. The categories for race and ethnicity were modeled after those denoted by the NIH[24].

Some studies used different categories for demographics. For example, one article reported race as 82% Caucasian, with no additional information pertaining to the race of the remaining 18% of participants[25]. In this case, the cohort representing 18% of participants were classified as other. Some articles also used categories such as other or unknown. Attention was paid to studies classifying participants as mixed or other race. If a study reported a specific category of mixed or more than one race, participants were classified as more than one race. Some articles reported race and/or ethnicity for a subset of the total number of participants; in

this event the remaining number of participants would be listed as other. In addition, some articles reported ethnicity as race and vice versa (according to the definitions used in this study), and the reported data was organized based on definitions above. All reported demographic information was included in data analysis.

Articles were categorized based on the disease focus of the study into one of the following groups: cancer, brain injury, cardiovascular or cerebrovascular, neurodegenerative and healthy aging, development (healthy and disordered), psychiatric (including substance abuse), all healthy, other neurological disease, and non-neurological disorder or more than one disease. Age of participants was classified based on the reported age range of all participants. If an article reported a mean and standard deviation but no range, the age range was estimated. The age ranges included infants (0-2 years old), children + adolescents (3-18 years old), mixed youth (0-18 years old), young adults (18-49 years old), older adults (≥49 years old), mixed adult (≥18 years old with no upper limit), across the lifespan (infants and/or youth and adults), and not reported. Articles were also categorized based on publisher. The categories for publisher were Nature, Elsevier, Springer, Wiley, professional society or association, academic or university publisher, PLoS, and other (publishers represented in ≤ 15 articles in the final data analysis). All analysis was conducted using IBM SPSS (v28). Percentage values within the text were rounded to the nearest whole percentage for simplicity, resulting in some total values not equal to 100%.

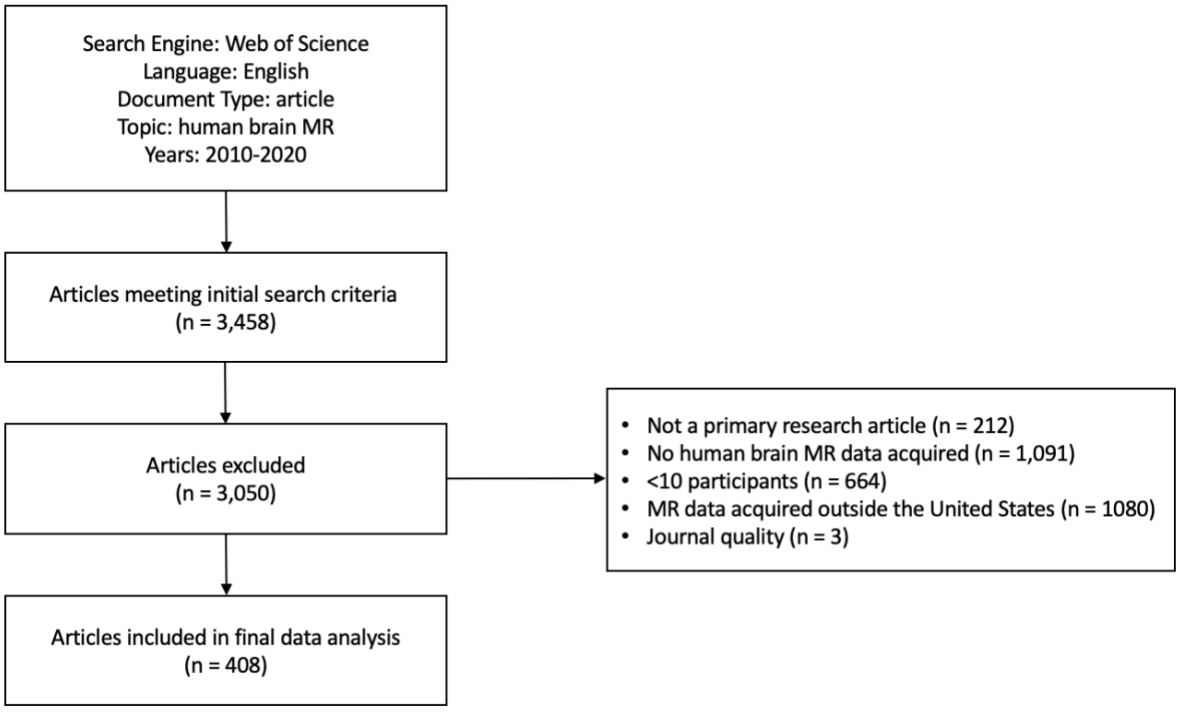

Figure 1. Flow chart for systematic review. Initial search criteria resulted in 3,458 articles for review. A total of 3,050 articles were excluded in the order shown above. The remaining 408 articles were included in the final data analysis. See Methods for further details.

Results and Discussion

Of 3,458 articles meeting initial search criteria, 408 were included. The highest reported demographic was biological sex, which was reported in 77% of the included articles (Figure 2). The second highest reported demographic was race at 10%, followed by 4% of articles reporting ethnicity (Figure 2). No significant trends were observed when evaluating the rates of reporting over time (Figure 3). All included studies and raw data are provided in Appendix 1.

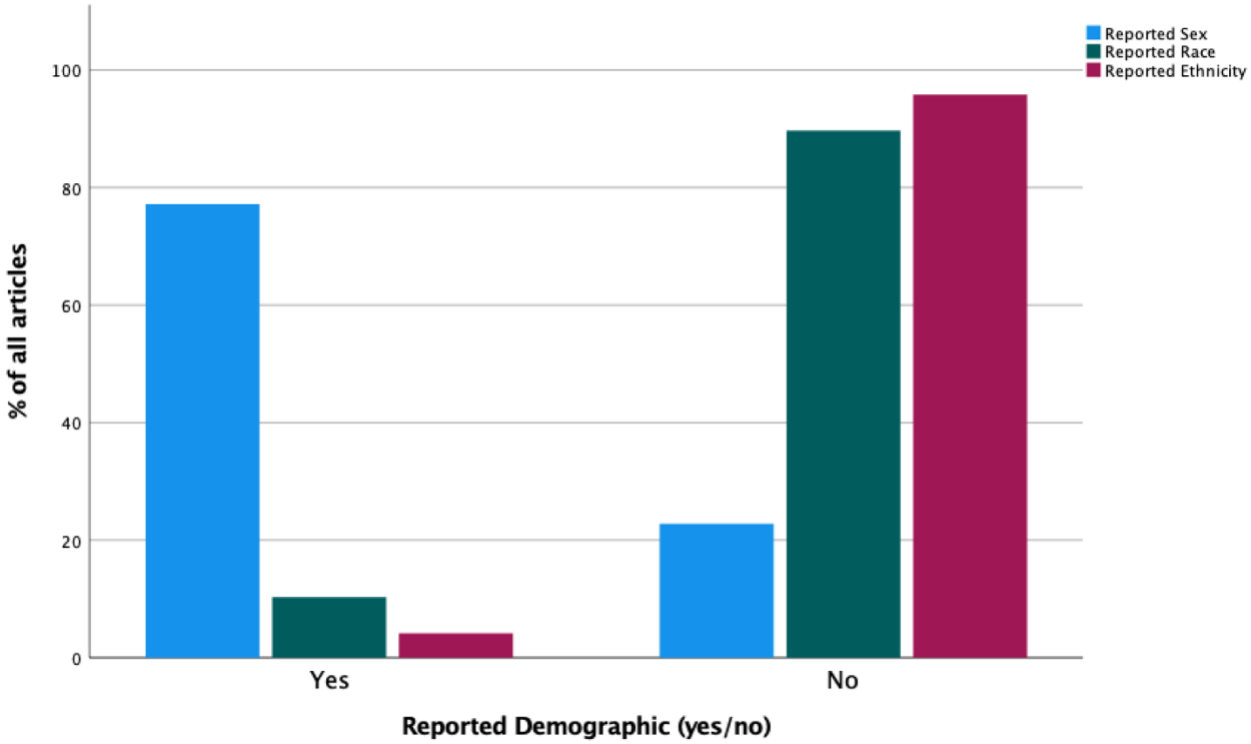

Figure 2. Overall rates of demographic reporting. Sex was reported at the highest frequency and in a majority of articles (n = 315, 77% of all articles). Race was reported by a minority of articles (n = 41, 10%). Ethnicity was reported at the lowest frequency, by a minority of articles (n = 17, 4%).

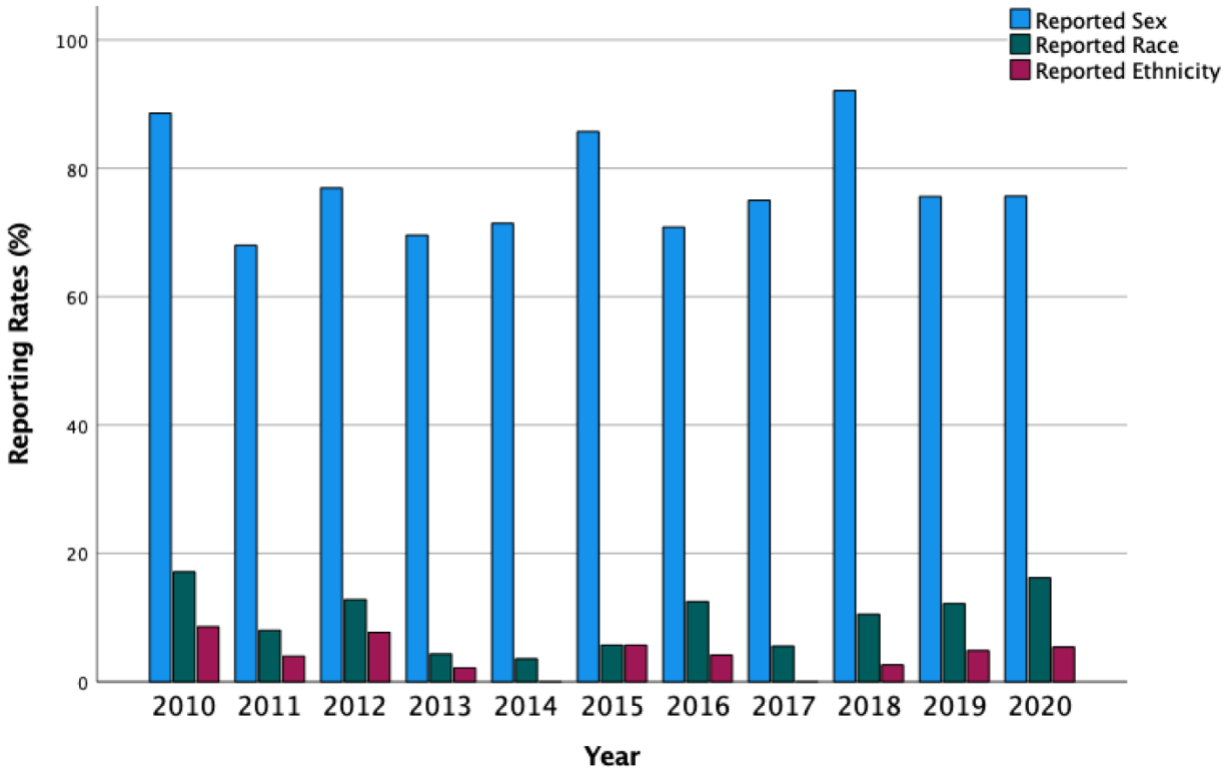

Figure 3. Reporting rates as a function of time. The rates of reporting for race, sex, and ethnicity are shown for each year. No apparent trends were observed as a function of time for race, sex, or ethnicity.

Biological sex is largely reported, and males and females are equally represented in neuroimaging studies

Of 408 studies included, 315 reported biological sex (77% of all studies) (Figure 2). Sex was reported in a majority of articles each year (Figure 3). While there was no clear trend (e.g., an increase) in the rate of reporting males and females (Figure 4), reporting rates vary between years. The highest inclusion of males was observed in 2010, 2011, 2012, and 2013, with 54% male subjects in each year, while the lowest inclusion rate for males was observed in 2017 at 44% (Figure 4). Both biological sexes were nearly equally represented in the total sample (males: n = 12,275, 51%; and females: n = 11,771, 49%) (Figure 5).

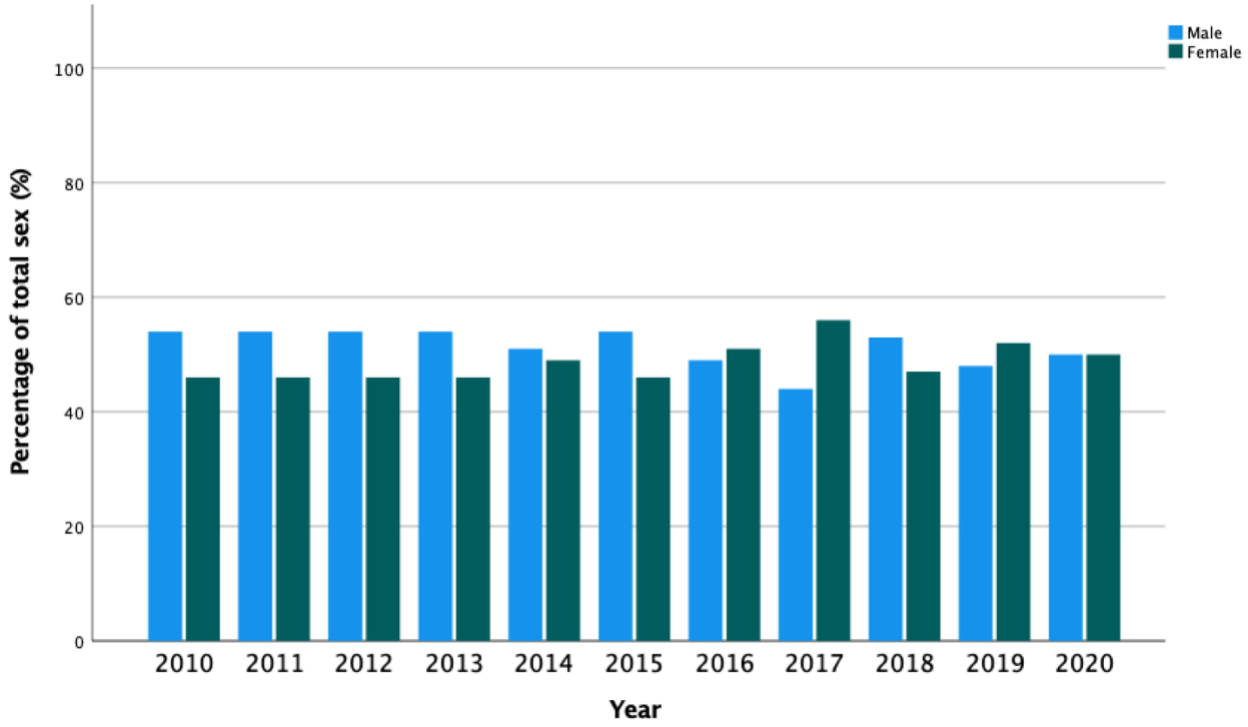

Figure 4. Inclusion of male and female participants as a function of time. The percentage of reported male and female are shown for each year. Males were represented as follows: 2010 (n = 1,065, 54%), 2011 (n = 519, 54%), 2012 (n = 611, 54%), 2013 (n = 1333, 54%), 2014 (n = 664, 51%), 2015 (n = 1,036, 54%), 2016 (n = 1,655, 49%), 2017 (n = 829, 44%), 2018 (n = 1,544, 53%), 2019 (n = 1,523, 48%), and 2020 (n = 1,496, 50%). Similarly, females were represented as follows: 2010 (n = 923, 46%), 2011 (n = 437, 46%), 2012 (n = 519, 46%), 2013 (n = 1,147, 46%), 2014 (n = 630, 49%), 2015 (n = 871, 46%), 2016 (n = 1,690, 51%), 2017 (n = 1,042, 56%), 2018 (n = 1,382, 47%), 2019 (n = 1,655, 52%), and 2020 (n = 1,475, 50%).

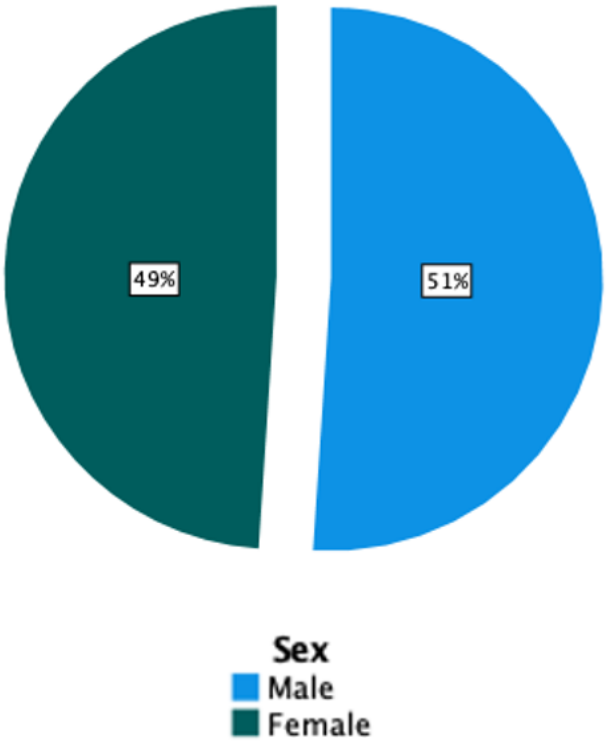

Figure 5. Inclusion of male and female participants. For all articles that reported sex (n = 315, 77% of all included articles), males represented 51% (n = 12,275) and females represented 49% (n = 11,771) of the total participants.

Prior literature reports higher representation of male subjects in research relative to the general U.S. population. Though we did not observe this in our review, one potential explanation for differences in representation between sexes is differing rates of volunteering. In a study aimed at sampling underrepresentation of personality types, Oswald et al. reported an approximately equal number of males and females were recruited (n = 56 and n = 58, respectively), indicating sex did not directly correlate with rates of volunteering[26]. After the study, participants were surveyed as to their willingness to participate in a more invasive study involving positron emission tomography (PET) and males were more likely than females to volunteer[26]. In contrast, a study by Ganguli et al. surveyed the attitudes of 1,702 individuals and observed females (n = 535, 58%) were more willing than males (n = 380, 42%) to volunteer for MRI research[27]. Further research is required to understand the impact of volunteer bias in neuroimaging studies and the effect of representation across sexes.

While most studies included both sexes, this does not equate to an understanding of sex-specific traits, which would require the use of sex as an explicit analytical variable. In 2021, Garcia-Siffuentes and Maney reported only a small percentage of biological studies properly assessed the impact and effect of biological sex[28]. Guidelines for researchers that provide instruction for methods to assess potential sex differences could be a useful next step in the future of neuroimaging studies to help account for sex as a biological variable.

Additional challenges arise when considering the distinctions between gender and sex. In this review, we reference gender as an individual's gender identity, and sex as biological sex[29]. We report all data indicated in articles by male or female as sex, but articles varied in their use of gender versus sex. For example, a study by Iltis et al. reported the gender of participants as either male or female[30]. In comparison, Wang et al. denoted sex of participants in the demographics table (59 male, 31 female)[31]. The different methods of categorization reflect one of the difficulties in characterizing demographic reporting in research.

Race and ethnicity are underreported in neuroimaging studies

Of the included 408 articles, 41 reported race and 17 reported ethnicity. Compared to the number of articles that reported sex (77%), rates of reporting race (10%) and ethnicity (4%) were

lower. There was no observable trend over time for the reporting of either race or ethnicity (Figure 3). Our findings are consistent with the trend observed by another review of a similar nature. Faniswala et al. reported among 393 clinical trials examining different neurological diseases (stroke, epilepsy, and Alzheimer's disease), only 20% of articles reported race, and ethnicity was reported in 14% of articles[32]. We also examined the rate of mutually inclusive reporting. For articles reporting race (n = 41, 10%) and ethnicity (n = 17, 4%), biological sex was reported 100% of the time. Of the 41 articles that reported race, 16 (39%) also reported ethnicity which is higher than the rate observed across all articles, suggesting a relationship between reporting sex and reporting race or ethnicity.

The total number of included participants across all studies was 36,312. The number of participants with reported race was 5,383 (15% of the total number of participants). Our reported racial demographics, therefore, only comprise a minority of the total population of participants across neuroimaging studies. Among participants with race reported, the majority was White (n = 2,924, 55% of participants with reported race) (Figure 6). Two racial groups included in this study were observably different from that reported in the U.S. Census: American Indian or Alaska Native and Asian or Pacific Islander. The American Indian or Alaska Native participants included in this review were reported at a higher percentage compared to the U.S. Census (15% vs. 1% (data.census.gov), respectively), while in contrast Asian or Pacific Islander participants were reported at a lower percentage relative to the U.S. Census (2% vs. 6%, respectively) (Figure 6). Of note, Suchy-Dicey et al. included 789 American Indian or Alaska Native participants, which comprised the majority of American Indian or Alaska Native participants across all included articles (99.6% of American Indian or Alaska Native participants with reported race)[33]. The authors stated their intention of including American Indian or Alaska Native participants to help combat historic underrepresentation in biomedical studies[33].

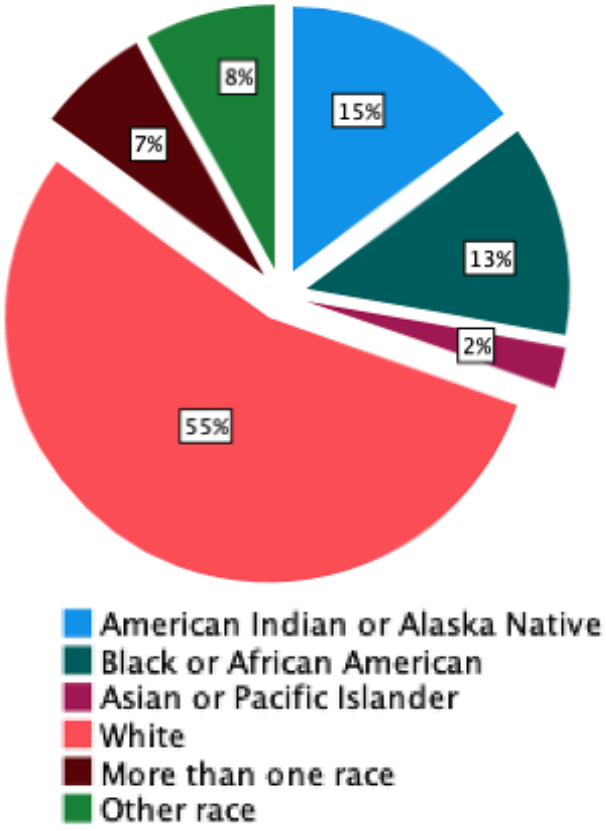

Figure 6. Reported racial diversity of neuroimaging participants. The majority of the subjects were White (n = 2,294 participants, 55%). The second highest reported race was American Indian or Alaska Native (n = 792, 15%), followed by Black or African American (n = 695, 13%), other race (n = 427, 8%), more than one race (n = 371, 7%), and Asian or Pacific Islander (n = 133, 2%).

In 2022, Reihl et al. reported on the diversity of participants in clinical trials that focused on neuro-epithelial central nervous system (CNS) tumors[17]. While the study did not report on articles from the same time duration (2000-2019) as this review (2010-2020), some comparisons can be drawn[17]. Across 662 studies, Reihl et al. reported racial and ethnic diversity of participants in clinical trials as American Indian (0.2%), Caucasian (90.5%), Asian/Other Pacific Islander (1.3%), African American (2.0%), other (4.0%), and Hispanic (2.0%)[17]. Both the reported diversity of neuroimaging studies in this review and neuro-epithelial CNS tumors in Reihl at al. report a majority of White participants. One notable difference was Reihl et al.

reported the least represented race as American Indian (0.2%), while we observed a much higher percentage of American Indian or Alaska Native participants (14.7%) (Figure 6). The data reflects that diversity can vary across neuroscientific fields.

Reporting the race and ethnicity of participants in neuroimaging studies can be a useful metric for further analysis. Despite limited evidence that genetics directly correlate with race, there exists sociological factors associated with race that could directly impact health. For instance, race may impact the level of care received by an individual. When examining the reported survival of glioma patients as a function of race, Ostrom et al. reported worse survival outcomes, and suggested differential access to healthcare due to race may be a contributing factor[34].

Despite the potential benefits of transparency, reporting race and ethnicity is challenging. A study by Spector et al. compared the accuracy of participants self-reporting their race and ethnicity when compared to genetically determined race or ethnicity, and observed participants' self-reported race did not always match their genetically determined race[35]. Out of 1,958 participants included, self-identified race differed from genetically determined ancestry for 186 participants[35].

Future studies could follow the example set by Suchy-Dicey et al., which intentionally increased the enrollment of historically underrepresented minorities. Researchers could assess the existence and extent of a lack of diversity across racial groups for various diseases by following the example set forth by the CDCAI, which aimed to recruit Native American participants to address the acknowledged lack of MRI data acquired from Native Americans[36]. Another example of targeted recruiting is observed in brain atlases and databases. Brain atlases, which are utilized for standardizing regions and coordinates to facilitate comparisons between individuals, rely on predetermined regions in the brain that have been identified through previously collected neuroimaging data[37]. One limitation in brain atlases, as evidenced by a systematic review evaluating 66 different brain atlases, is a lack of diversity among participants according to demographics such as age[37]. Further evidence from the Alzheimer's Disease Neuroimaging Initiative (ADNI), a large neuroimaging database, reported over 90% of participants in control, mild cognitive impairment, and Alzheimer' disease cohorts were White[38]. To address this, researchers have focused on increased or targeted enrollment of specific racial

groups, such as in the Chinese Brain Atlas and the Indian Brain Atlas[39,40], and may serve as a model for future studies.

Reporting varies according to disease of focus

Among 408 articles, the highest reported disease type was healthy (n = 153, 38% of all articles), followed by neurodegenerative and healthy aging (n = 56, 14%), and development (healthy and disordered) (n = 49, 12%) (Figure 7). Biological sex was reported at the highest rate in studies classified as psychiatric, including substance abuse (n = 33, 97% of psychiatric studies), followed by neurodegenerative and healthy aging (n = 51, 91%), and brain injury (n = 8, 89%) (Figure 8). In comparison, the lowest reporting of sex was observed in articles focused on all healthy participants (n = 106, 69%) (Figure 8). Only one disease group reported an equal representation of males and females; the reported sex in studies of all healthy individuals (n = 7,196) showed equal representation between males (n = 3,617, 50%) and females (n = 3,579, 50%) (Figure 9). It is also worth noting the healthy disease group comprised the largest number of articles in this present study (Figure 7). The largest reported sex imbalance was observed in brain injury studies (Figure 9). Across a total of 238 participants, males comprised the majority of subjects (n = 171, 72%) compared to females (n = 67, 28%).

The highest rates of reporting race were observed in studies focused on cardiovascular or cerebrovascular disease (n = 5, 45%), followed by psychiatric disease (n = 9, 27%), and non-neurological or more than one disease (n = 7, 17%) (Figure 8). In comparison, the lowest reporting of race was observed in articles focused on cancer (no articles reported race), neurodegenerative disease and healthy aging (n = 3, 5%), and all healthy (n = 8, 5%) (Figure 8).

The reported diversity also varied according to disease type. We observed White participants comprised the majority in several disease groups (Figure 10). When compared to the U.S. Census (data.census.gov) which reports White individuals as 62% of the population, White participants were represented at a higher rate in studies of four diseases (brain injury, development, psychiatric, and other neurological). The highest incidence of reporting White participants was in brain injury (n = 18, 90% of participants with reported race in brain injury studies), compared to the lowest in all healthy (n = 211, 32%) (Figure 10). Further examples

include Black or African American participants, which were reported at the highest incidence in neurodegenerative and healthy aging studies (n = 120, 38%) and the lowest incidence in stroke (n = 3, 0%) (Figure 10). Black or African American individuals comprise 12% of the U.S. population, and studies focused on brain injury, cardiovascular or cerebrovascular disease, and all healthy subjects reported lower percentages. Asian or Other Pacific Islander were also largely underrepresented (Figure 10).

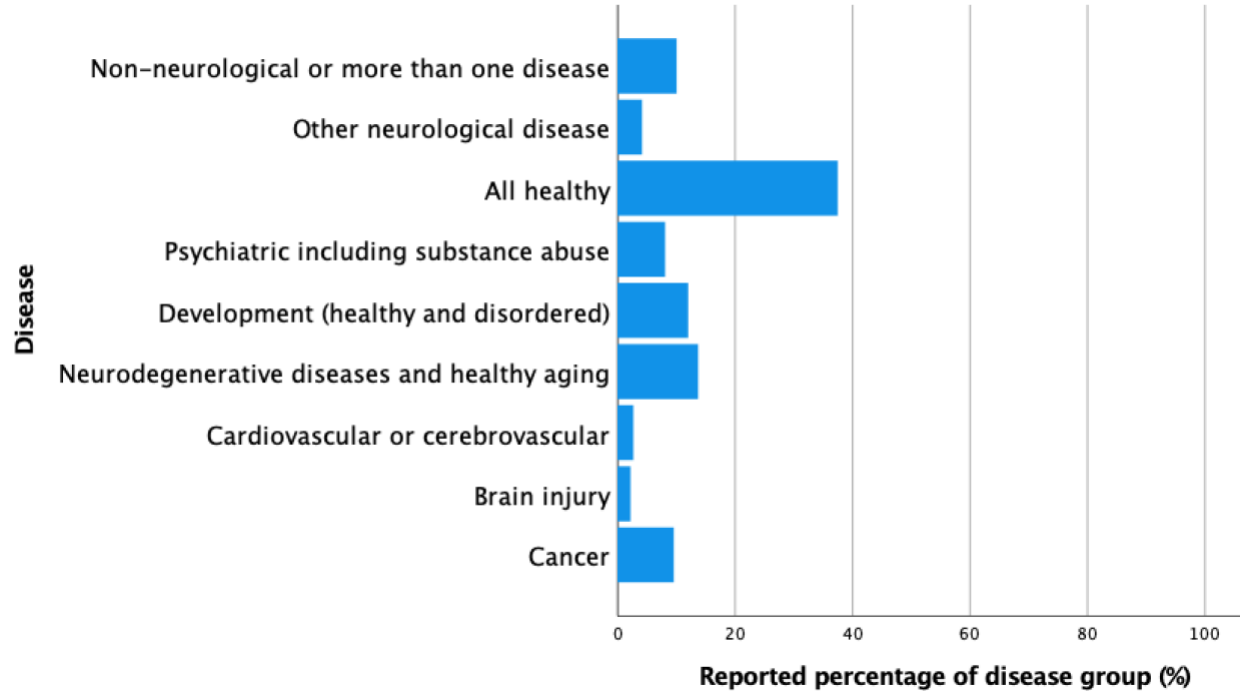

Figure 7. Disease focus for all included articles. Of all included articles (n = 408), most studies included all healthy participants (n = 153, 38% of all articles). The remaining articles were categorized into the following groups: cancer (n = 39, 10%), brain injury (n = 9, 2%), cardiovascular or cerebrovascular disease (n = 11, 3%), neurodegenerative and healthy aging (n = 56, 14%), development (healthy and disordered) (n = 49, 12%), psychiatric disease including substance abuse (n = 33, 8%), other neurological disease (n = 17, 4%), and non-neurological or more than one disease (n = 41, 10%).

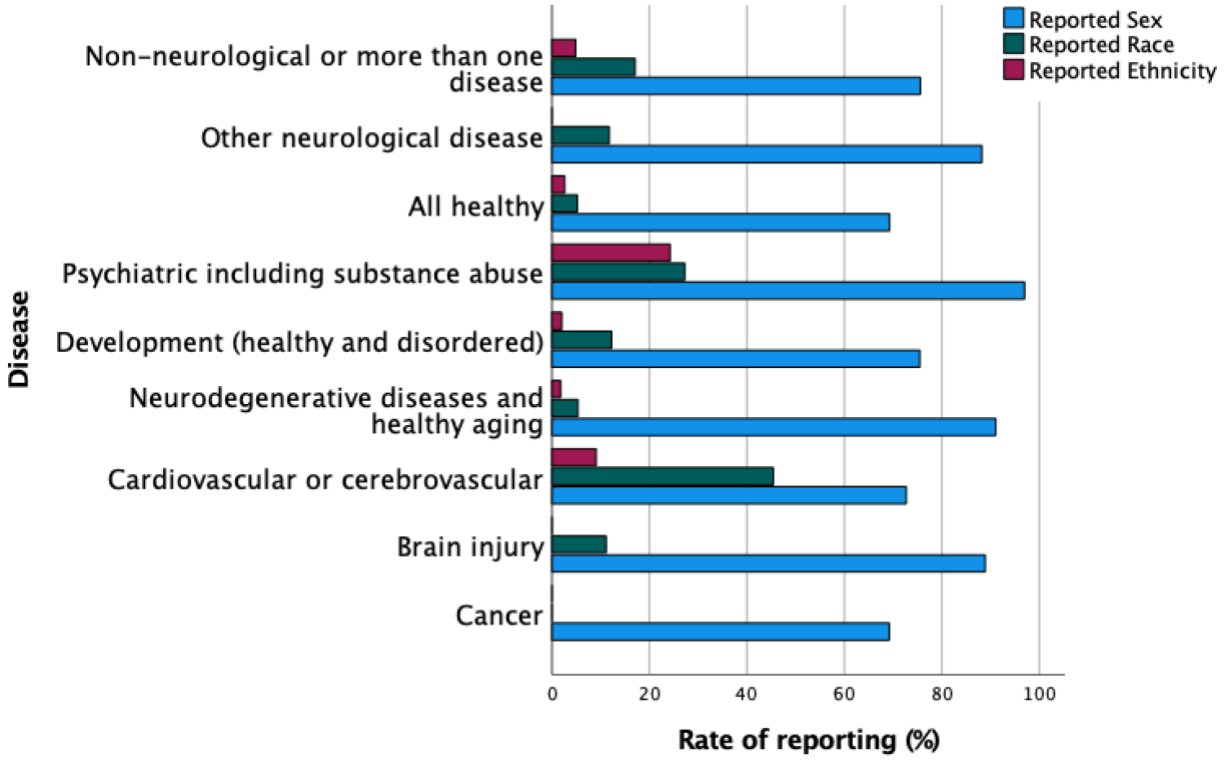

Figure 8. Rates of demographic reporting across disease groups. Across the nine disease groups, the reporting rates for sex, race, and ethnicity varied. For all disease groups, sex was reported in a majority of articles and race and ethnicity in a minority.

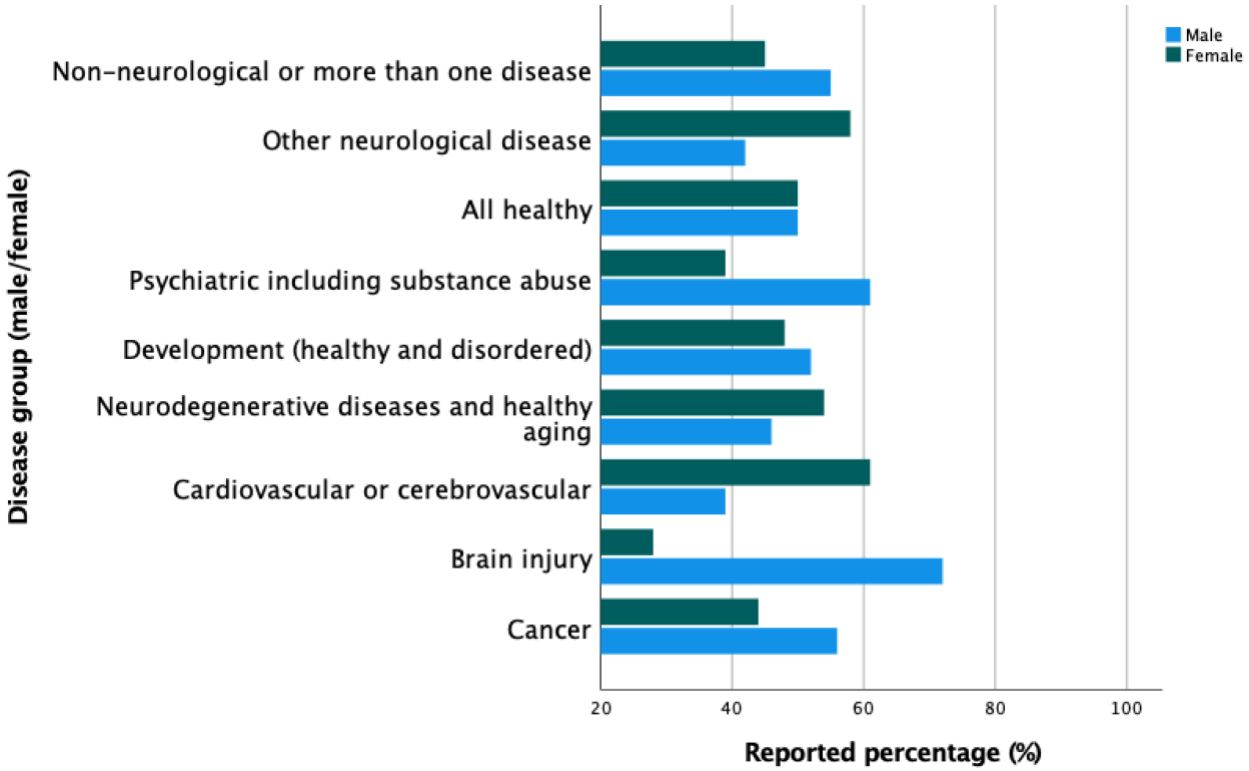

Figure 9. Inclusion of male and female participants as a function of disease group. The reported numbers of male participants for each disease focus were: cancer (n = 615 participants, 56%), brain injury (n = 171, 72%), cardiovascular or cerebrovascular (n = 784, 39%), neurodegenerative and healthy aging (n = 1,350, 46%), development (healthy and disordered) (n = 2,329, 52%), psychiatric including substance abuse (n = 1,397, 61%), all healthy (n = 3,617, 50%), other neurological disease (n = 280, 42%), and non-neurological or more than one disease (n = 1,732, 55%). The reported numbers of female participants were: cancer (n = 484, 44%), brain injury (n = 67, 28%), cardiovascular or cerebrovascular (n = 1,233, 61%), neurodegenerative and healthy aging (n = 1,578, 54%), development (healthy and disordered) (n = 2,114, 48%), psychiatric including substance abuse (n = 897, 39%), all healthy (n = 3,579, 50%), other neurological disease (n = 387, 58%), and non-neurological or more than one disease (n = 45%).

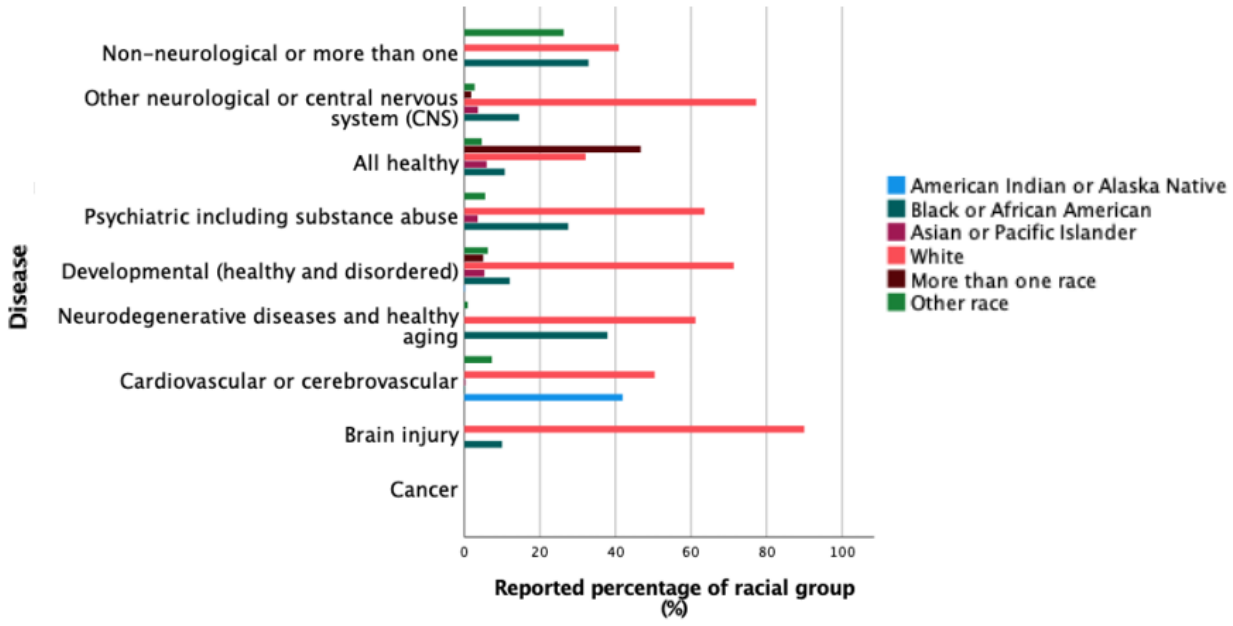

Figure 10. Reported racial diversity across disease group. Among the disease group with the highest diversity (all healthy), the most represented racial group was more than one race (n = 307 participants, 47% of reported participants were more than one race), followed by White (n = 211, 32%), Black or African American (n = 70, 11%), other race (n = 30, 5%), and Asian or Pacific Islander (n = 39, 6%). Most studies reported a majority of White participants: brain injury (n = 18 participants, 90%), cardiovascular or cerebrovascular (n = 949, 50%), neurodegenerative and healthy aging (n = 194, 61%), developmental (healthy and disordered) (n = 888, 71%), psychiatric including substance abuse (n = 350, 64%), other neurological (n = 85, 77%), and non-neurological or more than one (n = 229, 49%).

Reporting demographics varies across age cohorts

A plethora of variables such as age, environment, and socioeconomic status can influence brain anatomy, emphasizing the importance of diversity beyond ethnicity, race, and sex[41-44]. The majority of articles included young and older adult participants ≥18 years old (n = 133, 33% of all studies) (Figure 11). The second highest reported age group was adults between the ages of 18-49 (n = 107, 26% of all studies) (Figure 11). Articles that reported mixed youth participants (0-18 years) composed the smallest subsection of the final participant cohort (n = 10, 2% of

articles). The second smallest age group reported was children and adolescents ranging from 3-18 years old (n = 20, 5% of studies).

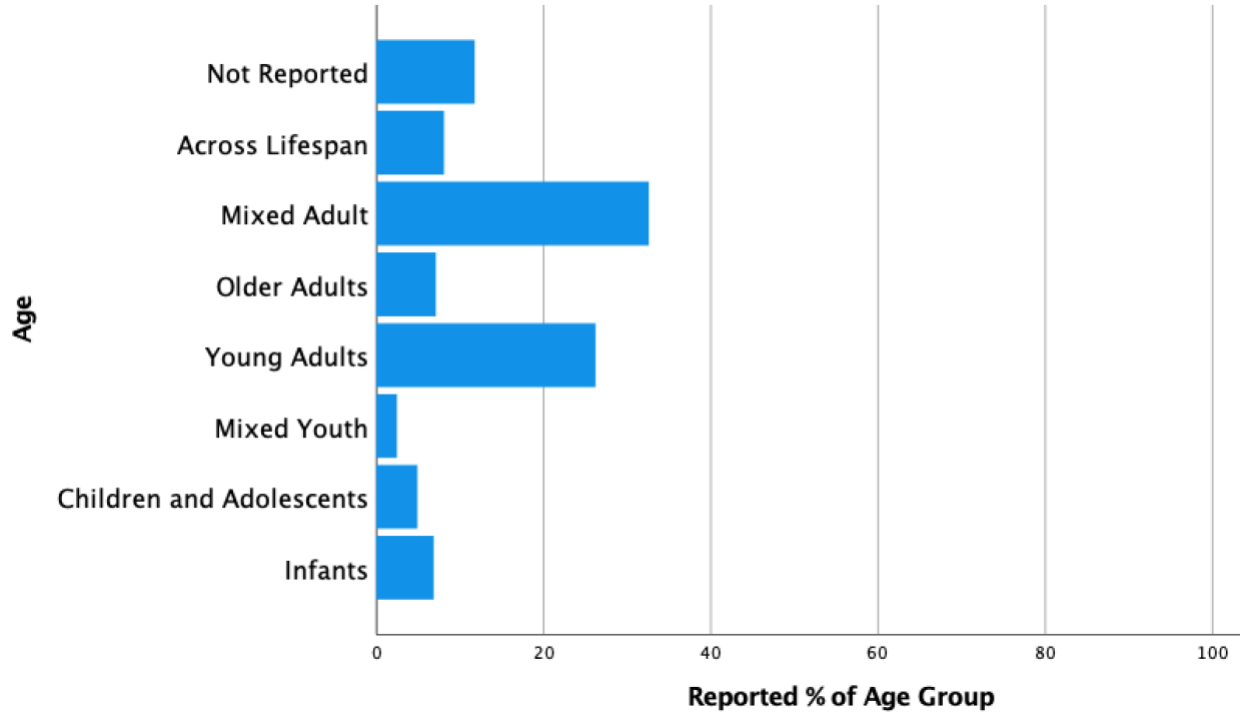

Figure 11. Reported number of articles per age group. For the 408 articles included, participants were categorized into eight age groups (see Methods). The highest reported age was mixed adults (18+ years old). The lowest reported age group was mixed youth (0-18 years old). The reported number of articles and percentages of the total sample of 408 articles were as follows: infant (n = 28, 7%), children and adolescents (n = 20, 5%), mixed youth (n = 10, 2%), young adults (n = 107, 26%), older adults (29, 7%), mixed adults (n = 133, 33%), across the lifespan (n = 33, 8%), and not reported (n = 48, 12%).

Demographic reporting varied between age groups. All but two groups reported sex in a majority of articles, mixed youth and not reported (Figure 12). The highest incidence for reporting sex (n = 19 articles, 95%), race (n = 8, 40%), and ethnicity (n = 3, 15%) was observed in articles including children and adolescents (Figure 12). The lowest incidence for reporting sex

(n = 8 articles, 17%), and ethnicity (n = 0, 0%) was observed when age was also not reported (Figure 12), suggesting when age was not reported, the article was less likely to report other demographic information (e.g., race, sex, ethnicity). The lowest incidence for reporting race (n = 0) was observed in articles including mixed youth (Figure 12).

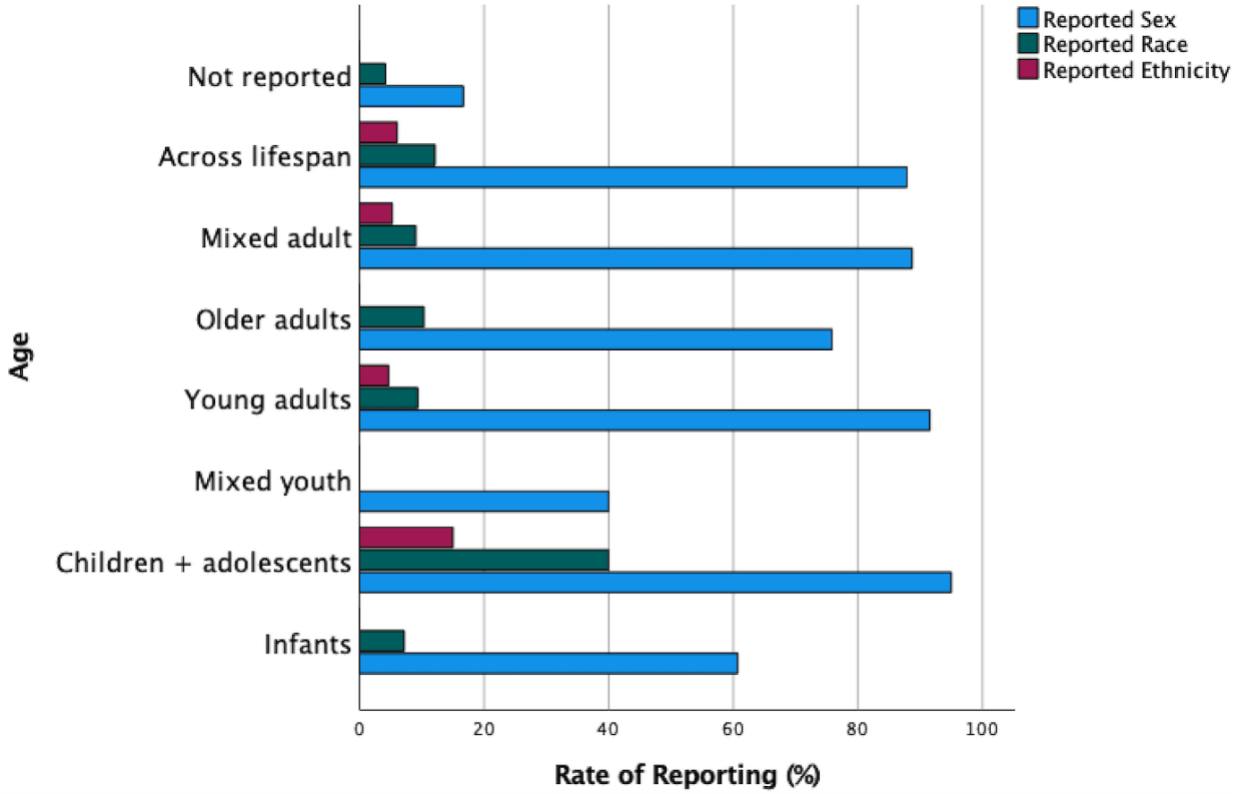

Figure 12. Rates of demographic reporting across age groups. Biological sex was reported in the majority of age cohorts, except for articles focused on mixed youth (n = 4,40%) and those that did not report age (n = 8,17%). Race was reported in ≤12% of articles for all age groups except for articles that included children and adolescents (n = 8, 40%). Ethnicity was not reported in four age groups (infants, mixed youth, older adults, and age not reported). The highest rate of reporting ethnicity was in articles that utilized children and adolescents (n = 3, 15%). The three remaining age groups (young adults, mixed adults, and across the lifespan) reported ethnicity in <6% of articles.

Reported racial diversity for age also provided more insight. Further analysis of the data reflected that in four out of the eight reported age groups, White participants represented the majority of participants (Figure 13). When looking at the reported racial diversity across age groups, infants, children + adolescents, older adults, and across the lifespan reported a majority of White participants (Figure 13). The mixed youth age group did not report the racial diversity of any participants. Across all age groups, Asian or Pacific Islander and more than one race always comprised a minority of the age cohort (Figure 13). American Indian or Alaska Native and Black or African American represented the majority of the age cohort in one instance each (mixed adult and not reported, respectively) (Figure 13).

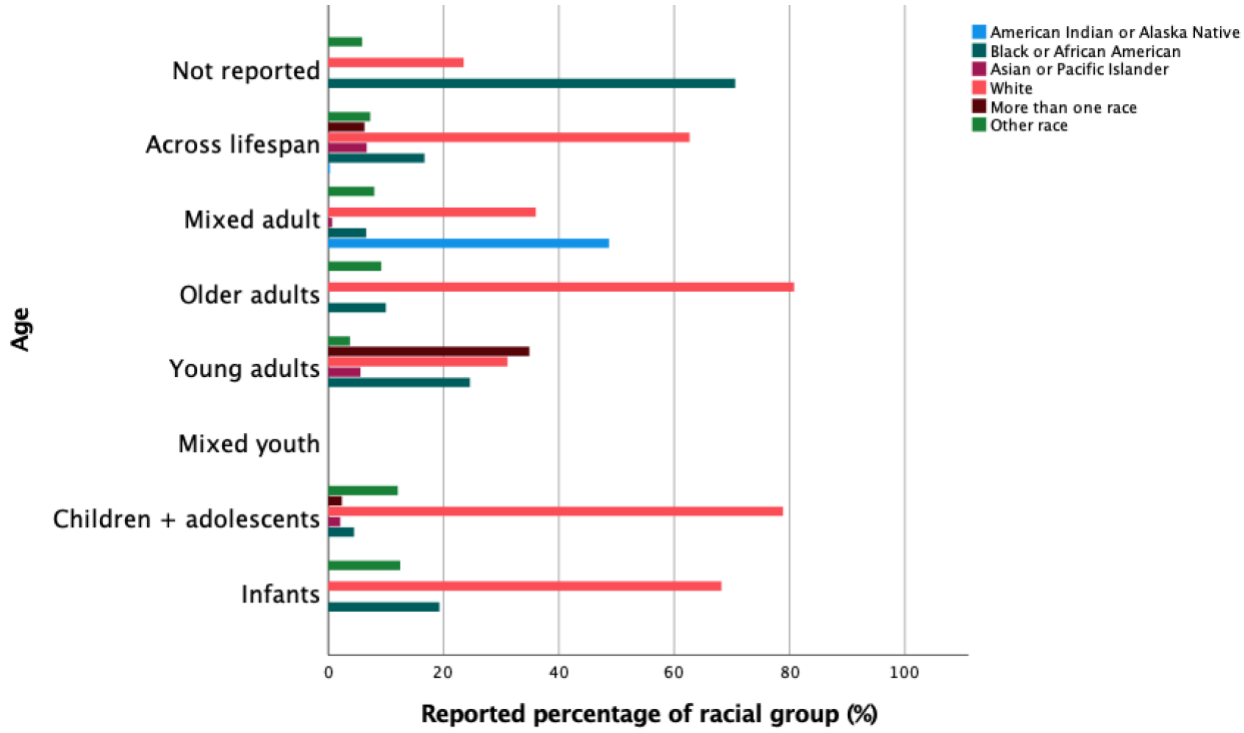

Figure 13. Reported racial diversity across age cohorts. A majority of age groups report primarily White participants. White participants comprised the majority of the age cohort for infants (n = 191, 68%), children and adolescents (n = 299, 79%), older adults (n = 958, 81%), and across the lifespan (n = 618, 63%).

Further analysis revealed differences in age groups in the inclusion of male and females. In the infant cohort, a total of 1,448 participants were represented and 777 (54%) were male and 671 (46%) were female (Figure 14). Similarly, of 1,527 participants in the child and adolescent cohort, 828 (54%) were male and 699 (46%) were female (Figure 14). Interestingly, the older adult cohort reported a higher number of females compared to males. A total of 2,062 participants were included, and 998 (48%) were male while 1,064 (52%) were female (Figure 14). A potential explanation is the longer life expectancy of females compared to males.

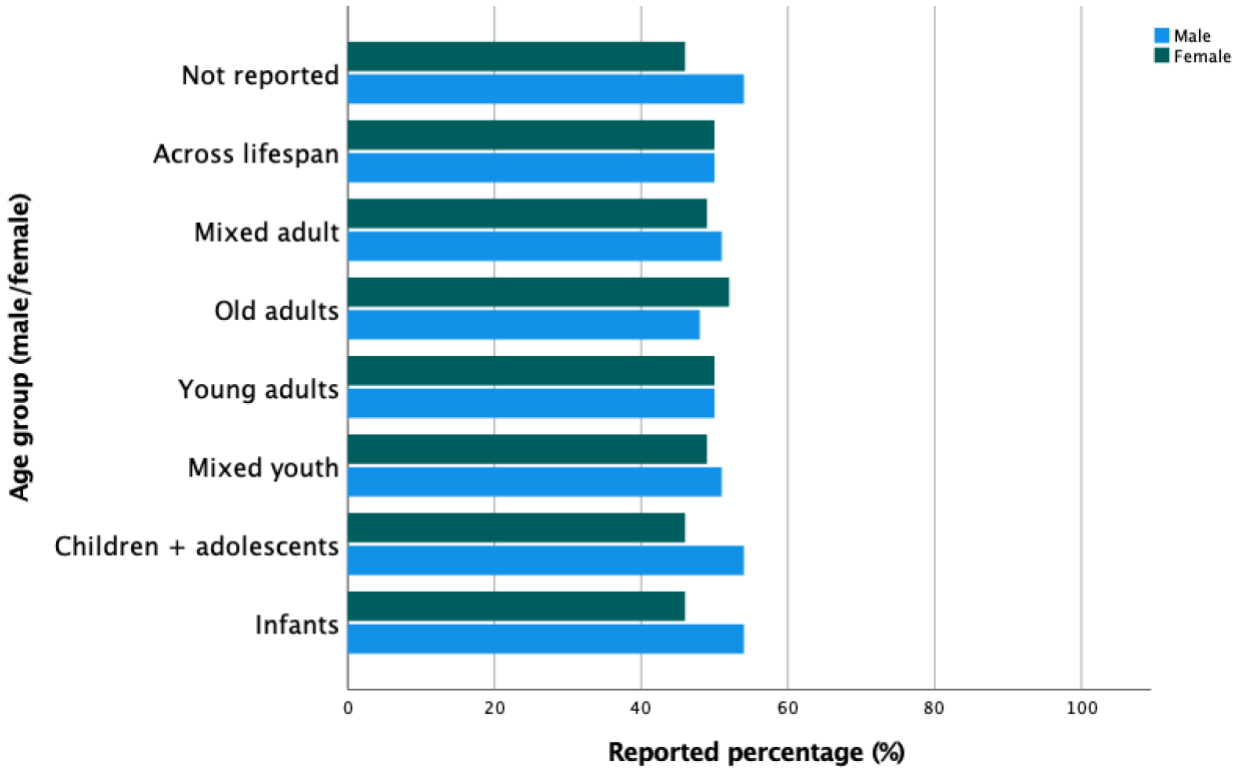

Figure 14. Inclusion of male and female participants as a function of age group. The reported numbers of male participants in each age group were: infants (n = 777, 54%), children and adolescents (n = 828, 54%), mixed youth (n = 419, 51%), young adults (n = 2,793, 50%), older adults (n = 986, 48%), mixed adult (n = 4,178, 51%), across the lifespan (n = 1,658, 50%), and not reported (n = 636, 54%). The reported number of female participants in each age group were: infants (n = 671, 46%), children and adolescents (n = 699, 46%), mixed youth (n = 407, 49%), young adults (n = 2,779, 50%), older adults (n = 1,060, 52%), mixed adult (n = 3,957, 49%), across the lifespan (n = 1,653, 50%), and not reported (n = 545, 46%).

NIH funding and reported diversity

The NIH Revitalization Act of 1993 mandates the inclusion of women and minorities in clinical research unless sufficient justification as to their exclusion is provided[45]. A total of 352 (86%) included studies reported at least a portion of funding from the NIH. Of those receiving NIH funding, 279 (79% of all articles that received NIH funding) reported sex, 37 (11% of all articles that received NIH funding) reported race, and 16 (4% of all articles that received NIH funding) reported ethnicity (Figure 15). Of the articles that did not receive NIH funding (n = 56, 14%), n = 36 (64%) reported sex, n = 4 (7%) reported race, and n = 1 (2%) reported ethnicity (Figure 15). Overall, higher rates of reporting were observed in studies reporting NIH funding compared to those reporting funding from other non-NIH sources.

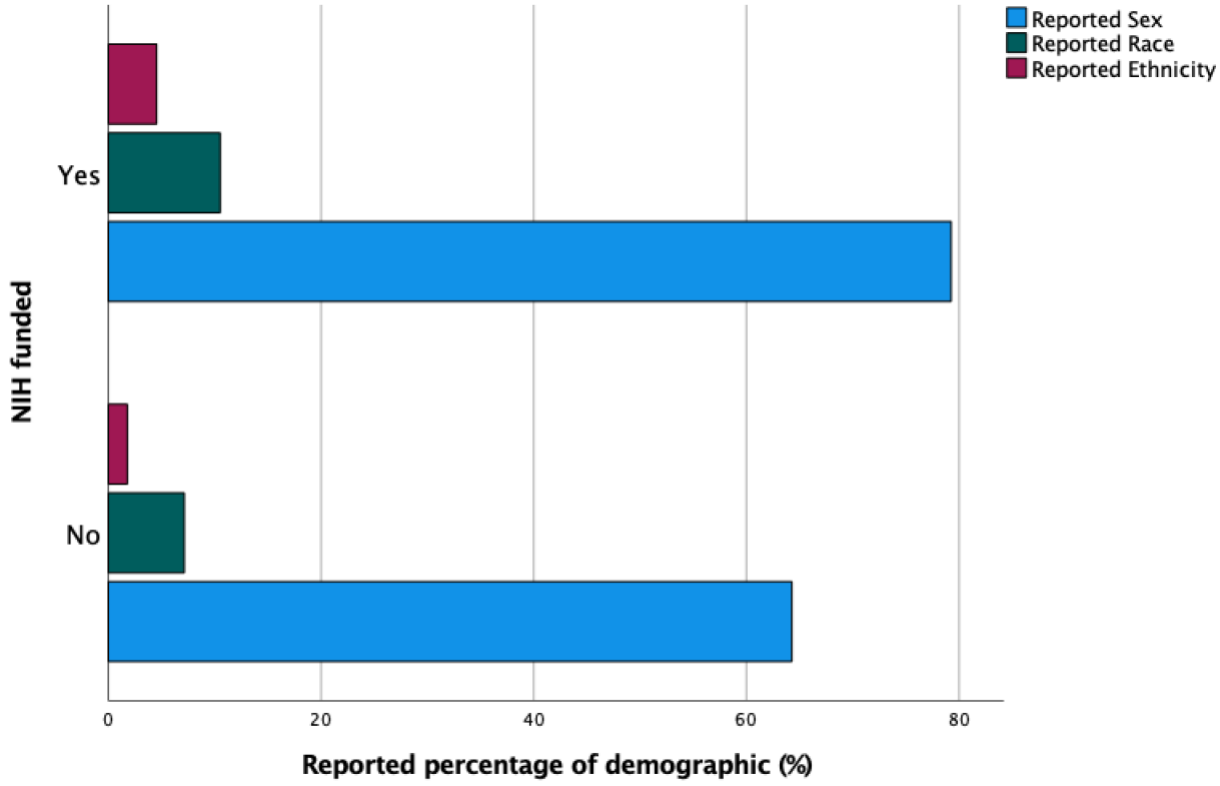

Figure 15. Reporting rates as a function of NIH funding. Articles that reported funding from the NIH (n = 279) reported higher rates of reporting sex (n = 279, 79%), race (n = 38, 11%), and ethnicity (n = 16, 5%) when compared to articles that did not report funding from the NIH (n = 56; sex (n = 36, 64%), race (n = 4, 7%), and ethnicity (n = 1, 2%)).

The highest reported demographic was sex. Males comprised the majority of participants in both NIH funded and non-NIH funded studies (Figure 16). Articles that received funding from the NIH reported nearly equal representation of males and females. Though similar, articles that did not report NIH funding included females at a lower rate (Figure 16).

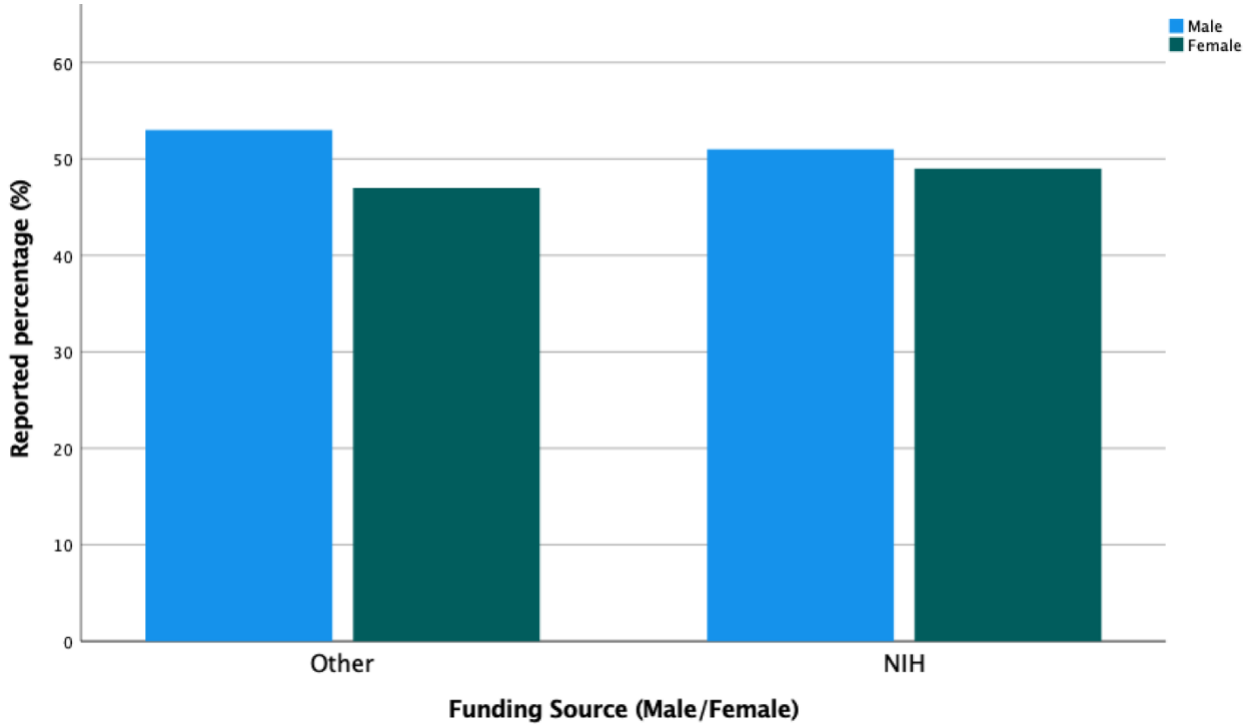

Figure 16. Inclusion of male and female participants as a function of funding source. The reported number of male participants differed slightly between other (non-NIH) funding (n = 2,382, 53%) and NIH funding (n = 9,893, 51%). The reported number of female participants were n = 2,095, 47% (other non-NIH funding) and n = 9,676, 49% (NIH funding).

While race was reported at similar rates regardless of NIH funding, there was a larger number of articles that received NIH funding. Of the 41 articles included in this study that reported race, n=38 (90%) reported funding by the NIH. Within the 38 studies that reported NIH funding and included race of participants, 5,259 participants had race reported, representing 14% of all included participants across all studies in this review. Racial diversity in studies reporting NIH funding was as follows: American Indian or Alaskan Native (n = 792 participants, 15% of participants in studies that received NIH funding that also reported race), Black or African

American (n = 628, 12%), Asian or Pacific Islander (n = 133, 3%), White (n = 2898, 55%), more than one race (n = 412, 8%), and other race (n = 396, 8%). One example of an article that received funding from the NIH but did not report diversity similar to the U.S. Census was conducted by Raji et al., which reported 88% of participants being White[46]. It is important to note while the NIH Revitalization Act of 1993 mandates the inclusion of women and racial/ethnic minorities, it does not provide specific guidelines for the diversity of included participants. The policy currently set out by the NIH only mandates the inclusion of women and minorities, unless their exclusion is justified[45].

Demographics reported as a function of publisher

Another metric used for data analysis was publisher information. Both the reporting rates and reported diversity varied across publisher. The publisher with the highest number of included articles was Elsevier (n = 129 articles, 31% of all included articles) and the second highest was Wiley (n = 100, 25%) (Figure 17). Both Elsevier and Wiley had the same percentage of articles that reported sex (n = 100, 78% and n = 78, 78%, respectively) and similar percentages of articles that reported ethnicity (n = 7, 5% and n = 3, 3%, respectively) (Figure 18). Reporting of race was higher in articles published by Elsevier (n = 14 articles, 11% of all articles published by Elsevier) compared to Wiley (n = 5, 5%) (Figure 18). The highest incidences of reporting sex were observed in articles published by Nature (n = 13 articles, 87%) and professional societies or associations (n = 58, 79%) (Figure 18). Similarly, the highest incidences of reporting race were those published by Nature (n = 5, 33% of articles published by Nature), Springer (n = 8, 29%), and other (n = 4, 13%). Ethnicity was reported at the highest rates in articles published in Nature (n = 3, 20%) and Springer (n = 3, 11%).

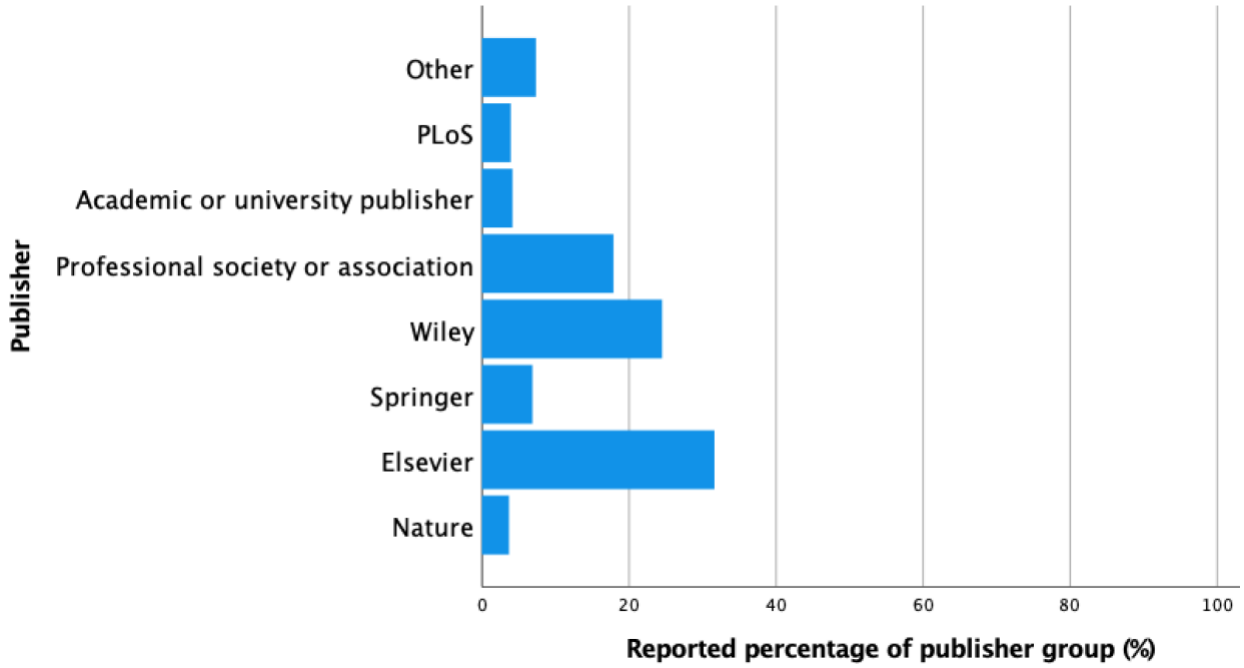

Figure 17. Reported number of articles as a function of publisher. For the 408 articles included in the final data analysis, each article was categorized based on publisher (see Methods). The reported representation in the total sample (n = 408) was Elsevier (n = 129 articles, 32%), Wiley (n = 100, 25%), professional society or association (n = 73, 18%), other (n = 30, 7%), Springer (n = 28, 7%), academic or university publisher (n = 17, 4%), PLoS (n = 16, 4%), and Nature (n = 15, 4%).

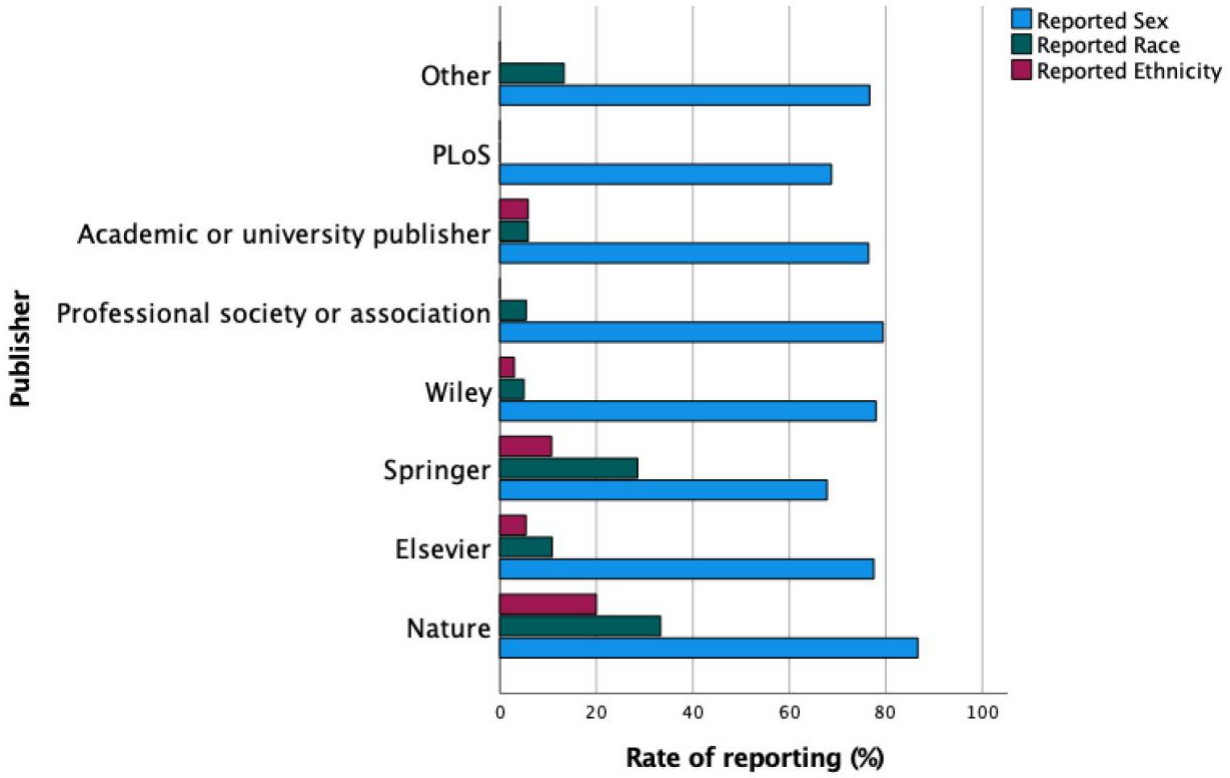

Figure 18. Rates of demographic reporting as a function of publisher. Biological sex was reported in a majority of articles across all publishers. The highest reporting rate for sex was observed in articles published by Nature (n=13, 87%), and the lowest reporting rate was in articles published by Springer (n=19, 68%). The highest reporting rate for race was observed in articles published by Nature (n=5, 33%), and the lowest in PLoS, as no articles reported race of participants. The highest rate of reporting ethnicity was observed in articles published by Nature (n=3, 20%). Ethnicity was not reported in any articles published by professional societies or associations, academic or university publishers, and PLoS.

Barriers to reporting in neuroscience and neuroimaging research

Potential barriers to diversity in neuroscientific research are vast. One barrier to diversity reported by Clark et al. was research study participants need to be within a reasonable travel distance[47]. Across the study, 45 patients, 7 physicians, 7 investigators, and 7 study coordinators were interviewed from various racial and ethnic minority groupings (Asian, African American, and Hispanic) and provided insight into the barriers that prevented diversity in clinical trials[47].

The overarching barrier was described as time and resource constraints, highlighting the difficulty in participating in trials despite interest, but a possible proposed solution was providing transportation to potential participants[47].

Medical mistrust experienced by multiple minorities provides additional barriers for participating in research. Trends in HIV treatment provide evidence that different racial groups experience different levels of medical trust and impact whether they are willing to seek out treatment[48]. Individuals often attribute previous difficulties experienced with medical settings as reasoning for medical mistrust[49]. In a study consisting of 143 Black individuals who received medical treatment, a majority (79%) reported experiencing racial discrimination[49]. If an individual has negative experiences influenced by their perceived race, they may be less likely to participate in future research studies.

Financial difficulties can also pose a barrier to diversity in clinical trials and health research. In a systematic review conducted by George et al., 44 articles were surveyed to understand barriers reported by racial and ethnic minorities to participating in research[50]. Of the 44 articles surveyed, 20 (45%) reported difficulties due to time and financial constraints[50]. Financial limitations can also be a limiting barrier for researchers. If a researcher has limited funds that will enable recruitment of a limited number of participants, diversity may be difficult to achieve. In addition, researchers must decide between equal representation or diversity along a pre-defined prevalence (such as U.S. Census or disease prevalence rate). Both strategies can result in a diverse cohort, but due to limited funding, a researcher may not be able to pursue both. An additional barrier to diversity in research can be language. If researchers and participants do not speak a common language, recruiting and study participation can also be challenging[51]. A study conducted by Durant et al. interviewed 91 individuals in various roles in clinical trials and reported language posed a barrier for the majority of participants interviewed (>50%)[51].

Outlook and future recommendations

This study had some limitations. First, reporting race as *other* for participants without specified race influences the relative percentages of the diversity reported. While some studies only reported X% of the race of their included participants, the remaining (100-X)% was

reported as other race; however, the racial classification could be any of the other reported racial groups. Second, both sex and gender, as reported in the articles, were classified as biological sex for our final analysis, limiting the ability to interpret the rates of reporting for sex and gender separately. It was also unclear if sex or gender was recorded from participants directly, or if the term gender was misused in this context. Individuals can have gender identities which do not correspond with biological sex. Researchers should record and report both biological sex and gender identity of participants. Third, while we did not categorize studies that analyzed sex, race, or ethnicity as an analytical variable, this is an important goal for future work. Finally, the reported racial diversity does not represent the true diversity of all participants in neuroimaging studies due to limited reporting rates.

Future efforts should encourage publishers and researchers to report the demographics of study populations, especially when regarding race and ethnicity. The data provided in this study suggests race and ethnicity are reported in a minority of neuroimaging studies. While a potential factor that contributes to limited diversity may be small sample sizes across neuroimaging studies, meta-analyses can provide a solution. To enable meta-analyses that include demographic variables, transparent reporting is required. Meta-analyses may facilitate future studies to examine topics such as race and ethnicity as a biological variable. Additional work can also be implemented for more broad data collection. Race, sex, and ethnicity are only three aspects of an individual. There is a plethora of other variables that could influence overall health such as socioeconomic status, level of education, and sexual orientation.

Conclusions

This review provides insight into the rates of demographic reporting in neuroimaging studies and the diversity that exists within. Overall, sex was reported in 77% of neuroimaging studies, race was reported in 10%, and ethnicity reported in 4%. Males and females were represented nearly equally among neuroimaging participants. Further work is required to consider the diversity in other neuroscientific fields, as well as to consider other demographics not included in this study. It is the responsibility of the researchers, academics, and all those involved in biomedical research to ensure transparency and scientific validity when including human participants in biomedical research.

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