Original Manuscript

SOUTHERN GERONTOLOGICAL SOCIETY

Journal of Applied Gerontology
1–10

DOI: 10.1177/0733464820954676
journals.sagepub.com/home/jag
SAGE

Mortality From Forces of Nature Among Older Adults by Race/Ethnicity and Gender

Rachel M. Adams[1], Candace M. Evans[1], Mason Clay Mathews[2], Amy Wolkin[3], and Lori Peek[1]

Abstract

Older adults are especially vulnerable to disasters due to high rates of chronic illness, disability, and social isolation. Limited research examines how gender, race/ethnicity, and forces of nature—defined here as different types of natural hazards, such as storms and earthquakes—intersect to shape older adults' disaster-related mortality risk. We compare mortality rates among older adults (60+ years) in the United States across gender, race/ethnicity, and hazard type using the Centers for Disease Control and Prevention's Wonder database. Our results demonstrate that older adult males have higher mortality rates than females. American Indian/Alaska Native (AI/AN) males have the highest mortality and are particularly impacted by excessive cold. Mortality is also high among Black males, especially due to cataclysmic storms. To address disparities, messaging and programs targeting the dangers of excessive cold should be emphasized for AI/AN older adult males, whereas efforts to reduce harm from cataclysmic storms should target Black older adult males.

Keywords

diversity and ethnicity, environment, mortality, gender

Introduction

Natural hazards do not impact people equally, with disparities driven by underlying social, economic, and political conditions. Injuries, death, and other adverse disaster outcomes are driven, in part, by historically rooted patterns of social inequality associated with age, gender, race/ethnicity, language proficiency, class, disability, and other sociodemographic characteristics (Cutter et al., 2003; Wolkin et al., 2015). Older adults—defined here as persons 60 years or older—are among the populations that have been recognized throughout the literature as being especially vulnerable before, during, and after a disaster (Peek, 2013). In comparison with other age groups, older adults are more likely to experience multiple chronic health conditions, which can become exacerbated during disaster events due to interruptions in routine care (American Red Cross, 2020; Mokdad et al., 2005). Age-related impairments, such as sensory, cognitive and mobility disabilities, as well as limited access to financial and social supports, can also interfere with the ability to process risk-related information, safely evacuate, and seek shelter during disasters (Aldrich & Benson, 2008; Fernandez et al., 2002; Trumbo et al., 2011). Despite these widely recognized risks, research suggests that older adults are insufficiently prepared for a large-scale emergency (Al-Rousan et al., 2014; Killian et al., 2017), further increasing their risk for poor outcomes. Vulnerable subgroups of older adults—such as those who are racial minorities or of lower income—face added barriers and may be especially underprepared for disasters (Cox & Kim, 2017).

Much of the existing research on older adult disaster vulnerability has focused on post-disaster psychological outcomes, responses to emergency information, and health morbidities more generally (Aldrich & Benson, 2008; Dosa et al., 2010; Fernandez et al., 2002; Mayhorn, 2005; Peek, 2013; Sirey et al., 2017; Srinivasan et al., 2014). Fewer studies have specifically examined older adults' disaster mortality, particularly in terms of the underlying cause of death from forces of nature recorded on a death certificate, as it can be difficult to classify relative to time since disaster and whether death is directly (i.e., caused by physical forces) or indirectly (i.e., caused by unsafe/unhealthy

Manuscript received: January 9, 2020; **final revision received:** August 3, 2020; **accepted:** August 12, 2020.

[1]University of Colorado Boulder, Boulder, CO, USA
[2]Arizona State University, Tempe, AZ, USA
[3]Centers for Disease Control and Prevention, Atlanta, GA, USA

Corresponding Author:
Rachel M. Adams, Natural Hazards Center and NHERI CONVERGE, University of Colorado Boulder, 483 UCB, Boulder, CO 80309-0483, USA.
Email: Rachel.Adams-1@Colorado.edu

conditions) related to a disaster (Wood & Bourque, 2018). There are, however, studies that have assessed death rates associated with particularly deadly events (Peek, 2013; Wood & Bourque, 2018). For instance, 63% of the deaths that resulted from Hurricane Katrina and nearly half of the deaths from Hurricane Sandy were among individuals 65 years and older (Brunkard et al., 2008; Prohaska & Peters, 2019; Seil et al., 2016). During the 2018 Camp Fire in Northern California—the deadliest wildfire in over a century in the United States—77% of the fatalities occurred among those over the age of 65 years (Newberry, 2019). In the 1995 Chicago heat wave, older adults were dramatically overrepresented among the dead (Klinenberg, 2002/2015; Whitman & Benbow, 1997). Research also suggests that mortality among older adults is shaped by hazard type. For example, studies have found that older adults have a much higher likelihood of death during tornadoes (Wood & Bourque, 2018) and in heat-related events (Curriero et al., 2002; Keatinge, 2003; Keatinge et al., 2000).

As disasters increase in frequency and intensity, and as the number of older adults expands in the United States, it is important to understand what factors influence mortality across a range of hazards and by specific subgroups in the population. The purpose of this study is thus to explore disaster mortality among older adults in the United States across gender, race/ethnicity, and forces of nature—defined here as different types of natural hazards, such as heat and cold exposure, storms, flooding, lightning, avalanches, earthquakes, and volcanic eruptions. Decades of research demonstrate that women experience limited access to health care, depend more on temporary housing, and are less likely to receive economic assistance following a disaster (Enarson, 2012; Enarson et al., 2018; Tobin-Gurley & Enarson, 2013). Moreover, racial and ethnic minorities are more likely to live in poorly constructed dwellings within close proximity to hazards and lack the economic resources to access disaster supplies and services (Bolin & Kurtz, 2018; Dash, 2013). Together these factors may contribute to increased vulnerability to different types of natural hazards among older adults.

A limited number of studies have used an intersectional lens to explore overlapping characteristics that may contribute to older adults' increased risk for mortality. Studies have found, for instance, higher mortality rates among lower income women in developing countries (Enarson et al., 2018; Neumayer & Plümper, 2006), while rates among older adult men may be higher in the United States (Brunkard et al., 2008; Klinenberg, 2002/2015). The relative increase in older men's mortality appears to be especially tied to race and ethnicity (Bolin & Kurtz, 2018). During Hurricane Katrina, for example, the mortality rate for African Americans was approximately 4 times that of Whites (Bolin & Kurtz, 2018), with older adult Black men having the highest mortality rate relative to other groups (Brunkard et al., 2008). In the 1995 Chicago heat wave, Black and White men were more likely to perish than Latino men living in neighborhoods with similar socioeconomic characteristics (Klinenberg, 2002/2015).

While the available literature provides important insights into the various factors that shape older adult disaster mortality, it is still unclear how these factors intersect to simultaneously influence mortality across a range of natural hazards. In the United States, which is one the most hazard-prone nations in terms of the number and costs of extreme climatological and geophysical events, there is no consensus on which hazard types have the highest mortality rate for older adults (Mileti, 1999). To address these gaps in the literature, we compare older adults' mortality rates in the United States across gender, race/ethnicity, and forces of nature. By elucidating how mortality rates among older adults are shaped by both sociodemographic and environmental characteristics, results from this study can help inform disaster preparedness and response efforts targeting at-risk populations with increased potential for vulnerability due to forces of nature.

Design and Method

This study used single underlying cause of death data published in the Centers for Disease Control and Prevention (CDC) Wonder database, which contains mortality and population counts for all U.S. counties from 1999 to 2017. Disaster mortality is determined by the National Center for Health Statistics using death certificates for all U.S. residents that attribute the death to "forces of nature." From 1999 to 2017, forces of nature as the underlying cause of death is classified according to the International Classification of Diseases, Edition 10 (ICD-10) codes X30 to X39. These include death caused by exposure to excessive natural heat; exposure to excessive natural cold; exposure to sunlight; victim of lightning; victim of earthquake; victim of volcanic eruption; victim of avalanche, landslide, and other earth movements; victim of cataclysmic storm; victim of flood; and exposure to other and unspecified forces of nature.

We calculated and graphed the age-specific mortality rates (${}_{n}M_{x} = {}_{n}d_{x}/{}_{n}p_{x} \times 100{,}000$) for all forces of nature for every 5-year age interval between 0 and 84 years from 1999 to 2017. Population counts were not publicly available for individuals 85 years or older via the CDC Wonder database (CDC, 2018b). While population estimates could be obtained via special request, data for this age group were not available for every year between 1999 and 2017. All analyses were thus restricted to ages 84 years and younger. We chose to define older adults as individuals older than 60 years so this included those aged 60 to 84 years in the database. The lower cutoff of 60 years, rather than 65 years which is often used in the literature, was chosen so that we would have a larger death count caused by such infrequent events to include in our analysis.

To compare mortality rates between genders, we calculated the standardized mortality ratios (SMRs) for males and females by dividing the number of actual deaths from 1999 to 2017 for each gender category by the number of expected deaths based on the distribution of each gender for every 5-year age interval. We graphed these SMR values for males and females for ages 0 to 84 years. Next, we calculated and graphed the SMRs for different racial/ethnic groups for every 5-year age interval between 0 and 84 years from 1999 to 2017. Because data were aggregated across 19 years and thus subject to changes in population dynamics over this time period, we also calculated SMRs for more discrete time intervals (1999–2004, 2005–2009, 2010–2014, 2015–2017) to compare with the aggregated data (1999–2017). We conducted Kolmogorov–Smirnov tests to determine if the SMR data for different racial/ethnic groups generated from each discrete time period differed from the aggregated data from 1999 to 2017.

To assess the intersectional effect of gender and race/ethnicity on mortality from forces of nature among older adults, we calculated and graphed SMRs for each racial/ethnic group stratified by gender. Next, we calculated age-specific mortality rates from each hazard type for older adults. Finally, we calculated the SMRs for each gender and race/ethnicity for the top three causes of death: exposure to excessive heat, exposure to excessive cold, and victim of cataclysmic storm. All analyses were conducted in Microsoft Excel.

Results

Between 1999 and 2017, there were 22,174 deaths from forces of nature across all ages 0 to 84 years. The crude mortality rate was 0.444 per 100,000 persons. Among older adults ages 60 to 84 years, there were 9,039 deaths, contributing to a crude mortality of 0.945 per 100,000 persons. Older adults had a 3.84-fold increase in mortality compared with those under 60 years. Older adult males had almost twice the rate of older adult females and American Indians/Alaska Natives (AI/ANs) had more than 4 times the rate of Whites (Table 1).

Figure 1 presents age-specific mortality rates for deaths due to forces of nature in the United States for ages 0 to 84 years from 1999 to 2017. Mortality from forces of nature follows a slightly elevated rate for infants, that decreases until the age of 9 years, and then increases again with every 5-year age interval.

Figure 2 presents the age-specific SMRs for males and females due to forces of nature for ages 0 to 84 years. The SMRs are greater than 1 for males and less than 1 for females at every age group except infancy ($<$1 years), indicating that mortality rates are consistently higher among males. The gendered differentials increase during childhood and peak between 20 and 29 years age range. The gendered differences in mortality steadily decrease with age but still remain for older adults.

Figure 3 presents age-specific SMRs across race/ethnicity. Across all ages, the AI/AN population has the highest mortality rate, followed by Blacks, Whites, Latinos, and Asians/Pacific Islanders. While the mortality rate for the AI/AN population peaks between 15 and 20 years old, it remains consistently higher than the other racial/ethnic groups at all ages. Mortality among the Black population steadily increases with age.

When we compared the SMR data from more discrete time intervals (1999–2004, 2005–2009, 2010–2014, 2015–2017) with the data from 1999–2017 using Kolmogorov–Smirnov tests, almost all the results were nonsignificant with the exception for Latinos between 2015–2017 and 1999–2017 ($D = 0.4444$ $p = .039$). Overall, these results suggest we cannot reject the null hypothesis that samples were drawn from the same distribution, so the additional analyses used data aggregated from 1999 to 2017.

Figure 4(A) to (E) presents the mortality curves stratified by gender for each racial/ethnic group for older adults (60–84 years). Among White older adults, females have higher standardized mortality ratios than males, but these differences shrink over time. Black and Latino males have a higher mortality than their female counterparts, and the difference remains relatively consistent with age. The gendered SMRs among older adult Asians/Pacific Islanders are very small and become negligible with age. For AI/AN older adults, males have consistently higher SMRs than females, with the greatest difference occurring between ages 60 and 65 years.

Table 2 presents 5-year age-specific mortality rates for older adults for different hazards characterized as forces of nature. Death rates are highest for exposure to excessive cold, followed by exposure to excessive heat, and victim of a cataclysmic storm. The confidence intervals do not overlap for these hazards, and the differences increase with age. Mortality rates for all other hazard types are negligible.

Table 3 presents the SMRs by gender for the top three causes of death from forces of nature. Mortality is consistently higher for older adult males, with the greatest difference for exposure to excessive cold, followed by exposure to excessive heat, and cataclysmic storms.

Table 4 presents the SMRs by race/ethnicity for the top three causes of death from forces of nature. For the AI/AN older adult population, mortality is particularly pronounced for exposure to excessive cold (SMR = 7.206), while mortality by excessive heat is more modest (SMR = 2.260), and is less than 1 for victim of a cataclysmic storm (SMR = 0.228). Among White (SMR range: 0.871–0.890) and Asian/Pacific Islander (SMR range: 0.227–0.345) older adults, the SMR values are less than 1 and more consistent across the three causes of death. Black older adults also have more consistency across the three forces of nature, though rates are elevated in comparison with other racial/ethnic groups and highest for cataclysmic storms (SMR = 2.470). Latino older adults have SMRs less than 1 for exposure to excessive cold (SMR = 0.439) and victim of cataclysmic storm (SMR = 0.408), but are moderately elevated for exposure to excessive heat (SMR = 1.201).

Table 1. Deaths by Forces of Natural Among Older Adults 1999–2017.

Older adults (60–84 years)	Death count	Population	Crude mortality rate per 100,000 [95% CI]
Male	5,604	435,012,563	1.288 [1.255, 1.322]
Female	3,435	521,176,657	0.659 [0.637, 0.681]
White	6,922	820,650,841	0.843 [0.824, 0.863]
Black	1,734	90,843,181	1.909 [1.819, 1.999]
Asian/Pacific Islander	94	37,846,836	0.248 [0.201, 0.304]
American Indian/Alaska Native	289	6,848,362	4.220 [3.733, 4.707]
Latino	420	70,217,982	0.598 [0.541, 0.655]
All	9,039	956,189,220	0.945 [0.926, 0.965]

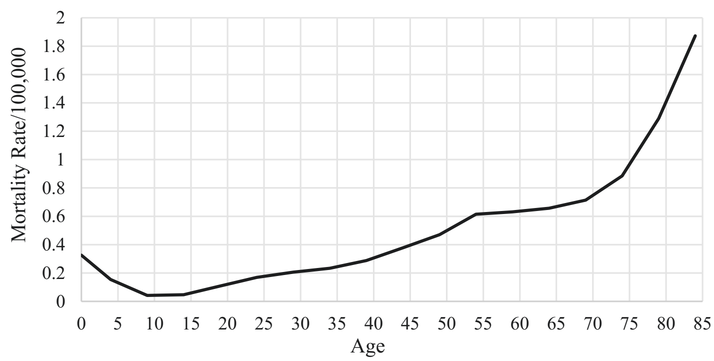

Figure 1. Age-specific mortality rates from forces of nature in the United States, 1999–2017.

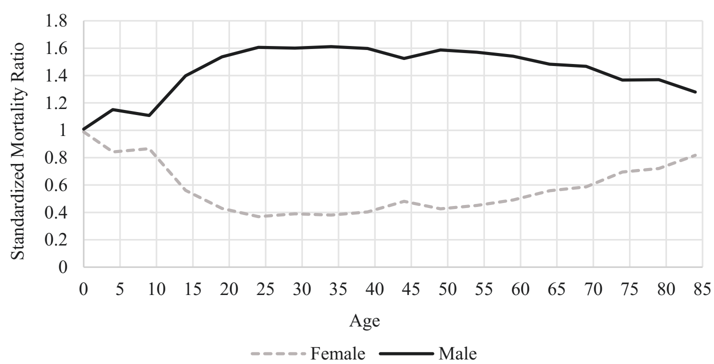

Figure 2. Standardized mortality ratios from forces of nature in the United States stratified by gender, 1999–2017.

Discussion and Implications

As the threat from extreme climatological and geophysical events continues to increase throughout the United States and globally (Wallemacq & House, 2018), it is essential to understand how different groups of people are affected and may be at risk for disaster-related mortality. This research addresses gaps in the literature by exploring how mortality from forces of nature is associated with age, gender, race/ethnicity, and hazard type over the past two decades. Our findings demonstrate how these factors intersect to shape disaster mortality trends among older adults. This research, which offers novel analyses using the CDC Wonder database, can help improve efforts to prevent or reduce death from disaster.

Our research revealed that the age-specific mortality rate for deaths associated with forces of nature exhibits a j-shaped curve, which is characterized by a slightly elevated rate for infants that then decreases until the age of 9 years, and then increases again with every age interval. The j-shaped curve is consistent with curves generated for all-cause mortality (Preston et al., 2001), suggesting that death from forces of

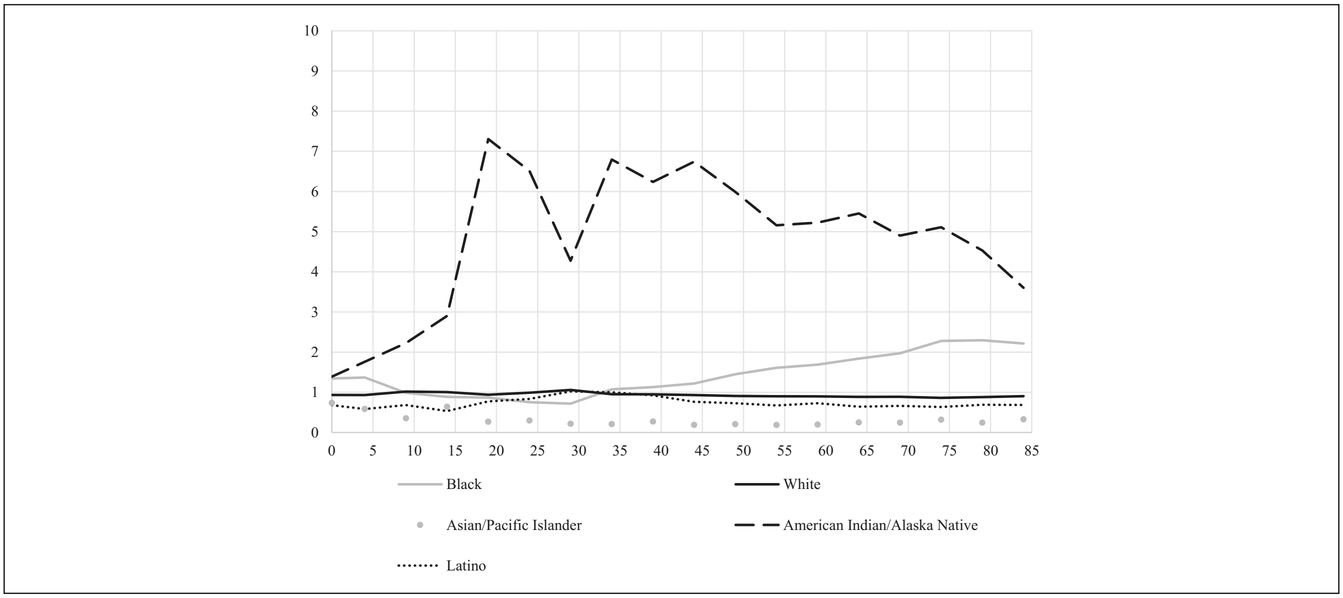

Figure 3. Standardized mortality ratios from forces of nature in the United States stratified by race/ethnicity (ages 0–84 years), 1999–2017.

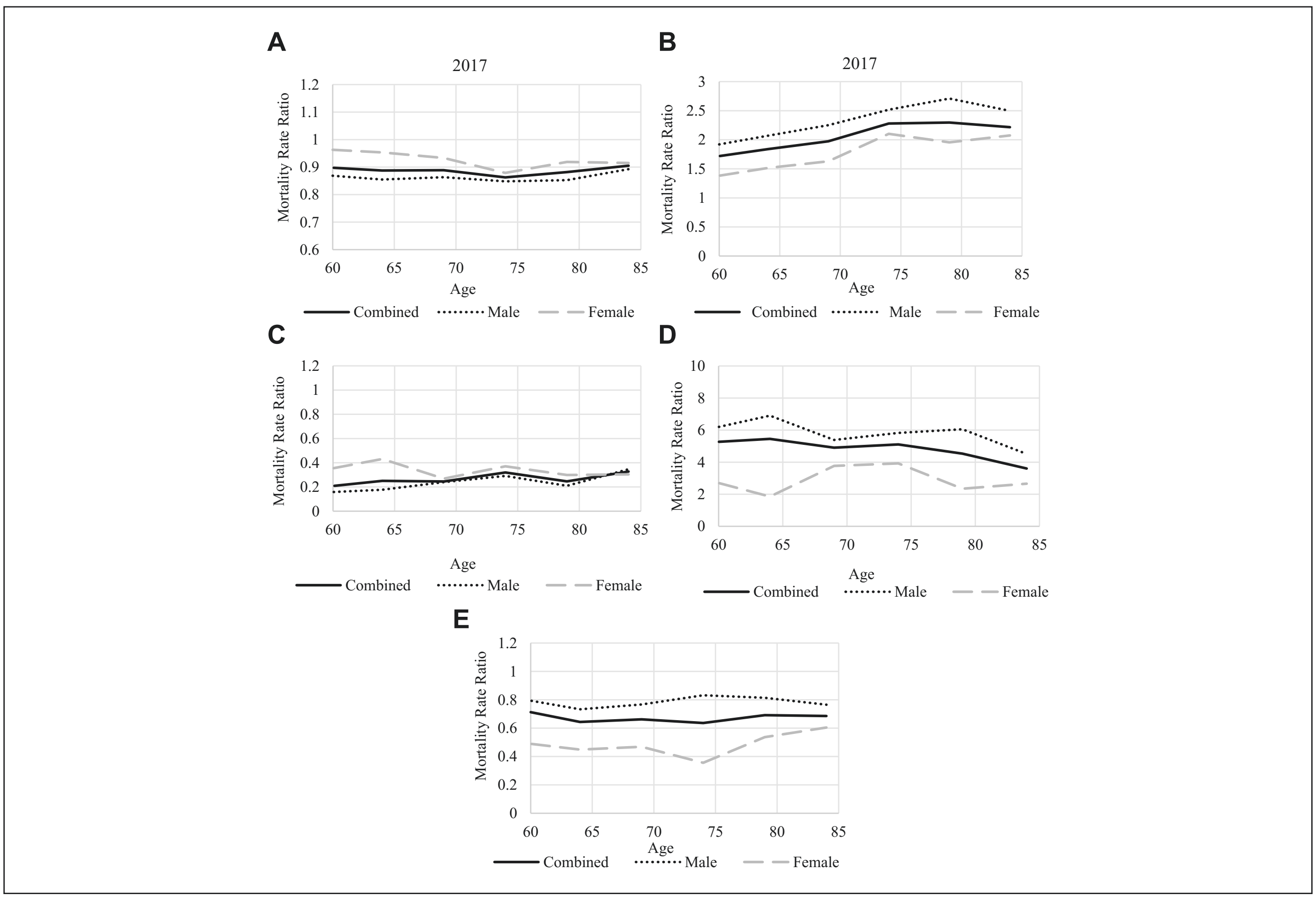

Figure 4. (A) Standardized mortality ratios from forces of nature in the United States among (A) Whites stratified by gender, 1999–2017; (B) Blacks stratified by gender, 1999–2017; (C) Asians/Pacific Islanders stratified by gender, 1999–2017; (D) American Indians/Alaska Natives stratified by gender, 1999–2017; and (E) Latinos stratified by gender, 1999–2017.

Table 2. Age-Specific Mortality Rates (per 100,000) by Age and Forces of Nature Among Older Adults (Ages 60–84 Years), in the United States, 1999–2017.

Age (years)	Excessive cold	Excessive heat	Unspecified forces of nature	Sunlight	Avalanche/landslide/ earth movement	Cataclysmic storm	Earthquake	Flood	Lightning	Volcanic eruption
Mortality rate [95% CI]										
60–64	0.357 [0.335, 0.378]	0.181 [0.166, 0.197]	0.010 [0.007, 0.014]	0.001 [0.000, 0.002]	0.008 [0.005, 0.012]	0.079 [0.069, 0.089]	0.000 [0.000, 0.000]	0.010 [0.006, 0.014]	0.011 [0.008, 0.016]	0.000 [0.000, 0.000]
65–69	0.372 [0.347, 0.397]	0.222 [0.203, 0.241]	0.015 [0.011, 0.021]	0.000 [0.000, 0.003]	0.004 [0.002, 0.008]	0.078 [0.067, 0.090]	0.000 [0.000, 0.000]	0.012 [0.008, 0.017]	0.009 [0.005, 0.013]	0.000 [0.000, 0.000]
70–74	0.470 [0.439, 0.502]	0.266 [0.243, 0.290]	0.020 [0.014, 0.028]	0.000 [0.000, 0.000]	0.002 [0.001, 0.006]	0.106 [0.091, 0.121]	0.000 [0.000, 0.000]	0.011 [0.007, 0.017]	0.010 [0.006, 0.016]	0.000 [0.000, 0.000]
75–79	0.705 [0.661, 0.748]	0.385 [0.353, 0.417]	0.029 [0.021, 0.039]	0.001 [0.000, 0.004]	0.001 [0.000, 0.005]	0.151 [0.131, 0.171]	0.001 [0.000, 0.004]	0.012 [0.007, 0.019]	0.005 [0.002, 0.010]	0.000 [0.000, 0.000]
80–84	1.118 [1.055, 1.182]	0.478 [0.436, 0.520]	0.048 [0.036, 0.063]	0.003 [0.001, 0.008]	0.000 [0.000, 0.000]	0.210 [0.183, 0.238]	0.000 [0.000, 0.000]	0.012 [0.007, 0.021]	0.004 [0.001, 0.010]	0.000 [0.000, 0.000]

Table 3. Standardized Mortality Ratios by Gender and Top Causes of Death From Forces of Nature in the United States Among Older Adults (Ages 60–84 Years), 1999–2017.

Gender	Excessive cold	Excessive heat	Cataclysmic storm
Male	1.431	1.364	1.166
Female	0.641	0.709	0.869

Table 4. Standardized Mortality Ratios by Race/Ethnicity and Top Causes of Death From Forces of Nature in the United States Among Older Adults (Ages 60–84 Years), 1999–2017.

Race/ethnicity	Excessive cold	Excessive heat	Cataclysmic storm
White	0.871	0.890	0.883
Black	2.083	2.229	2.470
Asian/Pacific Islander	0.262	0.345	0.227
American Indian/ Alaska Native	7.206	2.260	0.288
Latino	0.439	1.201	0.408

nature follows a similar trend where older adults are the most severely impacted. The highest overall mortality rates among the oldest age groups reflect previous literature examining disaster mortality and age (Wood & Bourque, 2018). High rates of chronic illness and disability, as well as diminished social and physical resources, likely increase the mortality risk among older adults (Mokdad et al., 2005; Peek, 2013), although there is a need for more nuanced and longitudinal analyses across hazard type and geographic location.

When gender is considered, the male and female SMRs reveal smaller gender differences at young and old ages and greater gender disparities between ages 20 and 60 years. Although gender effects decrease among older adults, male rates are still elevated suggesting that they are more vulnerable to death in disaster. While scholarship focused on developing countries suggests that women experience higher risk of mortality from disasters (Enarson et al., 2018; Neumayer & Plümper, 2006), our findings from the United States suggest that older adult males are at greater risk than older adult females, which is not surprising given the research on Hurricane Katrina (Brunkard et al., 2008; Sharkey, 2007) and the 1995 Chicago heat wave (Klinenberg, 2002/2015). This gendered pattern is also consistent with an earlier study that showed that the disaster-related death rate for male children is higher than the death rate for female children across all 0- to 24-year-old age cohorts (Zahran et al., 2008). Past literature suggests that societal gender norms, riskier behaviors, and greater social isolation among men and boys may contribute to the dynamic and complex ways that gender influences mortality (Enarson, 2012; Enarson & Pease, 2018; Tobin-Gurley & Enarson, 2013). However, as demonstrated in Table 3, the gendered trends in this study do not vary much by exposure to hazard type.

At all ages, clear disparities across race and ethnicity exist. The nonsignificant Kolmogorov–Smirnov tests confirm that these racial/ethnic trends remain similar over the past 20 years despite changes in U.S. demographics. The AI/AN population experiences disproportionate mortality burdens from all forces of nature, reaching as high as 7 times their White counterparts. The rates are most elevated during teen years, decrease in their 20s, increase again in their 30s, and then slowly decline with age. Although mortality from natural hazards does not continue to increase into old age, the SMRs remain about 3 to 5 times higher among AI/ANs in comparison with the Whites, demonstrating the persistence of disparities along racial/ethnic lines.

When SMRs for older adult AI/ANs are calculated for different forces of nature, it is apparent that these high rates are predominantly driven by exposure to excessive cold. While we were ultimately unable to make geographic comparisons by race/ethnicity and hazard type due to limitations in the data, one possible explanation for this finding is the prevalence AI/AN populations in northern latitudes with colder temperatures. A large proportion of AI/ANs live in northern states, such as Washington, Michigan, and Alaska (CDC, 2018a). However, an even larger proportion of AI/ANs resides in states with warmer temperatures, including Oklahoma, California, Arizona, New Mexico, and Texas (CDC, 2018a), suggesting that historically rooted inequalities may be more important than geography. AI/AN populations are more than 2 times as likely than Whites to live at the poverty level, so it is possible that they lack certain resources, such as access to indoor facilities with adequate heating, which may place them at greater risk during extreme cold spells in geographic areas with warmer climates. Moreover, AI/AN populations are subject to frequent and repetitive disaster losses, but research shows that less than one third of all federally recognized tribes have federally approved disaster mitigation plans (Carter, 2016; Carter & Peek, 2016). This means that a high proportion of this population may be unprepared when disaster strikes, and then they are left ineligible for federal post-disaster aid (Carter & Peek, 2016).

The Black population is the racial group with the second highest mortality, with SMRs reaching as high as double the value of the White population. These disparities increase into older age, suggesting a heightened intersectional vulnerability for Black older adults. Studies of past disasters support the findings that older adult African Americans experience higher risk of mortality from natural hazards (Bolin & Kurtz, 2018; Brunkard et al., 2008; Klinenberg, 2002/2015; Sharkey, 2007). Interestingly, the SMRs were highest for victims of a cataclysmic storm, which in terms of hazard type was less lethal for other racial groups. This finding may be triggered by the high proportion of African Americans residing in the hurricane-prone Southeastern United States. For instance, during Hurricane Katrina—one the deadliest disasters in modern history—African American older adults were the most likely to perish during this event (Brunkard et al., 2008; Sharkey, 2007). Living in more flood-prone areas with limited to access to transportation contributed to their increased vulnerability during Hurricane Katrina (Bolin & Kurtz, 2018; Dash, 2013). Across most causes of death, African Americans have the highest mortality rates due to inequalities in income, education, and occupation—all of which are related to lower preparedness levels and elevated risk of mortality (Cox & Kim, 2017; Dash, 2013).

When older adult mortality for each racial/ethnic group was stratified by gender, trends emerged that point to intersectional vulnerabilities. For instance, Black and AI/AN older adults experienced the greatest differences in age-specific SMRs by gender, with males approximately 2 times as likely to die as females. Latino older adult males also had a higher SMRs than older adult females, though overall mortality still remained low. White and Asian/Pacific Islander older adults, who experience lower than expected mortality, experienced the opposite trend where females were slightly more at risk. These findings demonstrate the importance of age, race/ethnicity, and gender and the ways that these demographic characteristics influence mortality from forces of nature in the United States.

Certain study limitations must be acknowledged. First, the CDC Wonder database contains some inconsistencies in data collection and death certification. To collect the data, the National Center for Health Statistics (NCHS) uses death certificates that are either coded by U.S. states and provided to NCHS through the Vital Statistics Cooperative Program or coded by NCHS from copies of the original death certificates that are provided by the State registration offices (CDC, 2018b). In addition, the CDC Wonder database may also contain some conflicts in death certification, as there have been changes to the ICD-10 codes over the study period, including those pertaining to forces of nature (CDC, 2018b). NCHS also notes that caution should be taken in interpreting mortality data for certain years due to high rates of underlying causes of deaths classified as "death due to other ill-defined and unspecified causes of mortality" in certain regions over the study period (CDC, 2018b). Together these factors may have contributed to some misclassification of deaths from forces of nature—however, relying on death certificates and using standardized ICD-10 codes likely enhances the overall validity of the data relative to other disaster outcome measures. Furthermore, examining data from almost two decades is a valuable contribution to the literature, as past studies have largely relied on mortality reported for specific disaster events.

Second, misclassification of race/ethnicity on death certificates may bias the mortality rates for different groups. This may be particularly true for the AI/AN population, as research suggests that misclassification of race/ethnicity on death certificates may be as high as 40% (Arias et al., 2016). Third, we were unable to obtain population data for individuals 85 years or older even after special request to NCHS, so our results are only generalizable to older adults in the range of 60 to 84 years. Given that this oldest age category may be the most vulnerable to natural hazards (Peek, 2013), this represents an important gap in understanding. Finally, while it would have been ideal to geolocate and map mortality by forces of nature by U.S. counties, as has been done in prior disaster mortality research on a shorter time scale (see Zahran et al., 2008), changing county boundaries and other inconsistencies in the data during our study time period prevented us from doing so. To further explore geographic differences, we attempted to generate mortality rates across U.S. states. Due to the small number of deaths in certain subpopulations, we were unable to generate mortality statistics due to NCHS data use restrictions. Many of the vital statistics were suppressed due to confidentiality constraints needed to protect personal privacy when there were nine deaths or fewer (CDC, 2018b). This prevented us from exploring geographical differences in rates across age, gender, race/ethnicity, and hazard type.

Despite the limitations, this study has several important implications for practice and research. Our findings suggest that future preparedness and response initiatives should target older adults with a specific focus on male racial/ethnic minorities. Efforts to enhance messaging around the dangers of excessive cold and to provide shelter during extreme cold events should specifically target AI/AN older adult males. To prevent death from cataclysmic storms, public health programs should address the specific needs of Black older adult males in hurricane-prone states. This may include focusing on issues related to lack of transportation and resources needed to safety evacuate as was observed in Hurricane Katrina (Dash, 2013). Although this study is mostly descriptive, future research can expand on our preliminary findings to elucidate the underlying factors that place specific subpopulations at risk. In turn, this can better inform even more focused preparedness and response initiatives that could ultimately save lives among the most vulnerable people in U.S. communities.

Authors' Note

Any opinions, findings, conclusions, or recommendations expressed in this journal do not necessarily reflect the opinions of the Centers for Disease Control and Prevention, the National Science Foundation, or the institutions with which the authors are affiliated.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The research was supported by the National Science Foundation, Division of Civil, Mechanical, and Manufacturing Innovation, Program on Humans, Disasters, and the Built Environment (NSF Award #1635593), with supplemental support from the Centers for Disease Control and Prevention (CDC).

ORCID iD

Rachel M. Adams https://orcid.org/0000-0002-5247-1360

References

Aldrich, N., & Benson, W. F. (2008). Disaster preparedness and the chronic disease needs of vulnerable older adults. *Preventing Chronic Disease: Public Health Research, Practice, and Policy*, *5*(1), 1–7.

Al-Rousan, T. M., Rubenstein, L. M., & Wallace, R. B. (2014). Preparedness for natural disasters among older US adults: A nationwide survey. *American Journal of Public Health*, *104*(3), 506–511.

American Red Cross. (2020). *Closing the gaps: Advancing disaster preparedness, response and recovery for older adults*. https://www.johnahartford.org/dissemination-center/view/report-advancing-disaster-preparedness-response-and-recovery-for-older-adults

Arias, E., Heron, M., & Hakes, J. K. (2016). The validity of race and Hispanic-origin reporting on death certificates in the United States: An update. *Vital and Health Statistics*, *2*(172), 1–21.

Bolin, R., & Kurtz, L. C. (2018). Race, class, ethnicity, and disaster vulnerability. In H. Rodriguez, W. Donner, & J. E. Trainor (Eds.), *Handbook of disaster research* (2nd ed., pp. 181–203). Springer.

Brunkard, J., Namulanda, G., & Ratard, R. (2008). Hurricane Katrina deaths, Louisiana, 2005. *Disaster Medicine and Public Health Preparedness*, *2*(4), 215–223.

Carter, L. (2016). *An investigation of United States federal policy attempts to reduce American Indian and Alaska Native disaster vulnerability* [Unpublished master's thesis]. Department of Sociology, Colorado State University.

Carter, L., & Peek, L. (2016). Participation please: Barriers to tribal disaster mitigation planning. *Natural Hazards Observer*, *40*(4). Natural Hazards Center, University of Colorado Boulder. https://hazards.colorado.edu/article/participation-please-barriers-to-tribal-mitigation-planning

Centers for Disease Control and Prevention. (2018a). *Tribal population*. https://www.cdc.gov/tribal/tribes-organizations-health/tribes/state-population.html

Centers for Disease Control and Prevention. (2018b). *Underlying cause of death, 1999-2017 results*. http://wonder.cdc.gov/ucd-icd10.html

Cox, K., & Kim, B. R. (2018). Race and income disparities in disaster preparedness in old age. *Journal of Gerontological Social Work*, *61*(7), 719–734.

Curriero, F. C., Heiner, K. S., Samet, J. M., Zegler, S. L., Strug, L., & Patz, J. A. (2002). Temperature and mortality in 11 cities in the eastern United States. *American Journal of Epidemiology*, *155*, 80–87.

Cutter, S. L., Boruff, B. J., & Shirley, W. L. (2003). Social vulnerability to environmental hazards. *Social Science Quarterly*, *84*(2), 242–261.

Dash, N. (2013). Race and ethnicity. In D. S. K. Thomas, B. D. Phillips, W. E. Lovekamp, & A. Fothergill (Eds.), *Social vulnerability to disasters* (2nd ed., pp. 113–138). CRC Press.

Dosa, D., Feng, Z., Hyer, K., Brown, L. M., Thomas, K., & Mor, V. (2010). Effects of Hurricane Katrina on nursing facility resident mortality, hospitalization, and functional decline. *Disaster Medicine and Public Health Preparedness, 4*(S1), S28–S32.

Enarson, E. (2012). *Women confronting natural disaster: From vulnerability to resilience*. Lynne Rienner.

Enarson, E., Fothergill, A., & Peek, L. (2018). Gender and disasters. In H. Rodríguez, W. Donner, & J. E. Trainor (Eds.), *Handbook of disaster research* (2nd ed., pp. 205–223). Springer.

Enarson, E., & Pease, B. (Eds.). (2018). *Men, masculinities, and disaster*. Routledge.

Fernandez, L. S., Byard, D., Lin, C. C., Benson, S., & Barbera, J. A. (2002). Frail elderly as disaster victims: Emergency management strategies. *Prehospital Disaster Medicine*, *17*(2), 67–74.

Keatinge, W. R. (2003). Death in heat waves: Simple preventive measures may help reduce mortality. *British Medical Journal*, *327*(7414), 512–513.

Keatinge, W. R., Donaldson, G. C., Cordioli, E., Martinelli, M., Kunst, A. E., Mackenbach, J. P., Nayha, S., & Vuori, I. (2000). Heat related mortality in warm and cold regions of Europe. *British Medical Journal*, *320*, 670–673.

Killian, T. S., Moon, Z. K., McNeill, C., Garrison, B., & Moxley, S. (2017). Emergency preparedness of persons over 50 years old: Further results from the health and retirement study. *Disaster Medicine and Public Health Preparedness*, *11*(1), 80–89.

Klinenberg, E. (2015). *Heat wave: A social autopsy of disaster in Chicago*. University of Chicago Press. (Original work published 2002).

Mayhorn, C. B. (2005). Cognitive aging and the processing of hazard information and disaster warnings. *Natural Hazards Review*, *6*(4), 165–170.

Mileti, D. S. (1999). *Disasters by design: A reassessment of natural hazards in the United States*. Joseph Henry Press.

Mokdad, A. H., Mensah, G. A., Posner, S. F., Reed, E., Simoes, E. J., Engelgau, M. M., & Vulnerable Populations in Natural Disasters Working Group. (2005). When chronic conditions become acute: Prevention and control of chronic diseases and adverse health outcomes during natural disasters. *Preventing Chronic Disease*, *2*(Spec No), Article A04.

Neumayer, E., & Plümper, T. (2006). *The gendered nature of natural disasters: The impact of catastrophic events on the gender gap in life expectancy, 1981-2002*. London School of Economics.

Newberry, L. (2019, February 10). Poor, elderly and too frail to escape: Paradise fire killed the most vulnerable residents. *Los Angeles Times*. https://www.latimes.com/local/lanow/la-me-ln-camp-fire-seniors-mobile-home-deaths-20190209-story.html

Peek, L. (2013). Age. In D. S. K. Thomas, B. D. Philips, W. E. Lovekamp, & A. Fothergill (Eds.), *Social vulnerability to disasters* (2nd ed., pp. 167–198). CRC Press.

Preston, S. M., Heuveline, P., & Guillot, M. (Eds.) (2001). *Demography: Measuring and modeling population processes*. Blackwell.

Prohaska, T. R., & Peters, K. E. (2019). Impact of natural disasters on health outcomes and cancer among older adults. *The Gerontologist, 59*(Suppl. 1), S50–S56.

Seil, K., Spira-Cohen, A., & Marcum, J. (2016). Injury deaths related to Hurricane Sandy, New York City, 2012. *Disaster Medicine and Public Health Preparedness*, *10*(3), 378–385.

Sharkey, P. (2007). Survival and death in New Orleans: An empirical look at the human impact of Hurricane Katrina. *Journal of Black Studies*, *37*, 482–501.

Sirey, J. A., Berman, J., Halkett, A., Giunta, N., Kerrigan, J., Raeifar, E., Artis, A., Banerjee, S., & Raue, P. J. (2017). Storm impact and depression among older adults living in hurricane Sandy–affected areas. *Disaster Medicine and Public Health Preparedness*, *11*(1), 97–109.

Srinivasan, S., Llorente, M. D., & Magley, M. (2014). Mental health consequences of disaster exposure in older adults. In C. Cefalu (Ed.), *Disaster preparedness for seniors* (pp. 311–327). Springer.

Tobin-Gurley, J., & Enarson, E. (2013). Gender. In D. S. K. Thomas, B. D. Phillips, W. E. Lovekamp, & A. Fothergill (Eds.), *Social vulnerability to disasters* (2nd ed., pp. 139–165). CRC Press.

Trumbo, C., Lueck, M., Marlatt, H., & Peek, L. (2011). The effect of proximity to Hurricanes Katrina and Rita on subsequent hurricane outlook and optimistic bias. *Risk Analysis: An International Journal*, *31*(12), 1907–1918.

Wallemacq, P., & House, R. (2018). *Economic losses, poverty, and disasters: 1998-2017*. Centre for Research on the Epidemiology of Disasters, United Nations Office for Disaster Risk Reductions.

Whitman, S., & Benbow, N. (1997). Mortality in Chicago attributed to the July 1995 heat wave. *American Journal of Public Health*, *87*, 1515–1518.

Wolkin, A., Patterson, J. R., Harris, S., Soler, E., Burrer, S., McGeehin, M., & Greene, S. (2015). Reducing public health risk during disasters: Identifying social vulnerabilities. *Journal of Homeland Security and Emergency Management*, *12*(4), 809–822.

Wood, M. M., & Bourque, L. B. (2018). Morbidity and mortality associated with disasters. In H. Rodriguez, W. Donner, & J. E Trainor (Eds.), *Handbook of disaster research* (2nd ed., pp. 357–383). Springer.

Zahran, S., Peek, L., & Brody, S. D. (2008). Youth mortality by forces of nature. *Children Youth and Environments*, *18*(1), 371–388.