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Advances in Estimating Mortality Associated With Tropical Cyclones in the US

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Tropical cyclones are closed, rotating systems of thunderstorms that form over warm ocean waters and range from tropical depressions (winds less than 39 mph), to tropical storms (winds of 39-73 mph), to hurricanes (winds of 74 mph or higher). Tropical cyclones periodically produce some of the deadliest disasters in the US. The 1900 Galveston hurricane, for example, ranks as the highest-fatality meteorological event in US history, projected to have accounted for between 6000 to 12 000 deaths. That storm accounted for half of the recorded deaths from 165 US mainland hurricanes for the entire 20th century.[1] Yet historically, using traditional conventions for assessing mortality, the majority of US hurricanes have been thought to result in relatively modest death tolls, averaging less than 100 documented deaths per storm.[1]

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The report by Parks and colleagues[2] in this issue of *JAMA* illustrates how official tallies may significantly underestimate the full extent of tropical cyclone-associated mortality. The authors reconceptualized how cyclone-associated mortality can be assessed to capture excess deaths. Specifically, they accounted more fully for mortality by (1) extending the observation interval to 6 months after landfall, (2) expanding the geographic scope to all counties experiencing cyclone wind days, (3) examining mortality from tropical systems with wind speeds ranging from tropical depression to major hurricane force, (4) moving beyond direct injury and considering a wider range of potential causes of death, and (5) focusing on the demography of mortality by incorporating the Centers for Disease Control and Prevention Social Vulnerability Index.[3]

The authors present an aggregated analysis of 33.6 million deaths that occurred in 1206 tropical cyclone–exposed counties in the continental US from 1988-2018. The analysis shows that, at the county level, each additional tropical cyclone day was associated with increased county-level death rates in the month following the cyclone for 5 of 6 causes of death analyzed, including injuries (3.7%), infectious and parasitic diseases (1.8%), respiratory diseases (1.3%), cardiovascular diseases (1.2%), and neuropsychiatric conditions (1.2%), but not for cancers.

Several key points emerge from this study and require consideration in the context of a future in which harmful weather events are likely to become even more commonplace and affect more US residents than today.[4]

First, one of the shortcomings of current approaches to quantifying tropical cyclone mortality is the brief window of observation typically used. Official records of tropical cyclone deaths generally include only deaths from direct exposures to cyclone hazards that occurred during landfall and in the first hours and days after a storm.[1] Examples of acute phase deaths that have been enumerated historically include blunt trauma from wind-borne debris, electrocutions from downed power lines, or drownings in vehicles attempting to navigate flooded roadways.[5]

Parks et al[2] extended the mortality observation period to 6 months following the storm event. Their analyses demonstrated that tropical cyclone deaths do not cease once the wind and water hazards diminish or dissipate. Rather, cyclone deaths accrue over multiple months as deaths among storm survivors occur related to austere conditions, environmental exposures, and disrupted health systems that characterize the postdisaster landscape.

Second, as illustrated in the maps in the article by Parks et al[2] portraying cyclone-affected counties, the geographic scope of cyclone wind exposures extends to counties that incorporate 48% of the population of the continental US. Tropical cyclones do not simply make landfall in coastal counties and disperse; many systems remain intact as they traverse large swaths of land, bringing powerful wind and water hazards far inland. The maps show tropical cyclone mortality frequently extending 3 or more counties inland from the Atlantic seaboard and the perimeter of the Gulf of Mexico.

Some storm systems travel even further distances. As a recent example, Hurricane Ida, the most powerful Atlantic hurricane of 2021, made landfall in Louisiana at peak Category 4 intensity on August 29 and caused the deaths of an estimated 32 people along the Gulf Coast. Over the next 2 days, the system moved steadily eastward and northward through the southeastern and mid-Atlantic states, reemerging and intensifying over open ocean as it affected parts of Pennsylvania, New Jersey, New York, and Connecticut, where 56 deaths were recorded.[6] As this example and the study by Parks et al[2] demonstrate, where a hurricane makes landfall is not necessarily the only location where loss of life may occur.

Third, Parks et al[2] make an important contribution by examining all episodes of Atlantic windstorms over a 30-year period, ranging from tropical depressions with gale-force winds to major hurricanes.[2] While prior research has often focused on the most extreme cyclones, this report shows that storms with lesser wind speeds can still cause substantial physical harm. For instance, fatal motor vehicle crashes can occur when motorists drive in gale-force winds and tropical storm conditions, although these deaths are often overlooked in mortality counts that only consider hurricanes.

Prior research has shown that water hazards, including storm surge and inland flooding, account for more deaths than wind hazards.[5] Moreover, extreme precipitation rates and flash floods have occurred in systems with winds well below hurricane force. Most of 2017 Hurricane Harvey's 33 trillion-gallon deluge, for example, occurred in areas that experienced sub-hurricane-force winds.[7]

Fourth, enlarging the scope of the mortality analyses to include more potential causes of death further illuminates the range of health consequences of tropical cyclones. In so doing, Parks et al[2] found elevated mortality rates in cyclone-affected counties from injuries and also from infectious and parasitic diseases, cardiovascular diseases, respiratory diseases, and neuropsychiatric conditions.[2]

This more inclusive approach to estimating excess tropical cyclone–associated mortality was conducted for Puerto Rico's population of 3.5 million residents after Hurricane María traveled diagonally across the length of the island on September 20, 2017. The official death toll initially released for María was 64, an estimate based on the usual practice of tallying impact-phase injury and drowning deaths associated with direct exposure to storm hazards.[8] Over the longer term, the widespread devastation, prolonged power outages, and profound damage to health systems proved to be associated with higher mortality than the initial passage of the hurricane through the island. Subsequent analyses estimated that 2000 to 5000 deaths had occurred during the 5 months following the storm's landfall.[8,9] Excess deaths were concentrated among people experiencing poverty, medically fragile populations, older adults, people with inadequately treated noncommunicable diseases, and those lacking access to health care.[8,9]

Fifth, the incorporation of the Social Vulnerability Index into the 30-year analyses by Parks et al[2] reaffirms the expectation that excess tropical cyclone mortality is highest for the most vulnerable tertile of the population.[3] This finding illustrates that health consequences of disasters, including fatalities, are experienced disproportionately by the most socially marginalized and economically disenfranchised segments of the US population.

The report by Parks et al[2] is a valuable contribution to the literature and helps to expand current conceptualizations of tropical cyclone–related mortality in novel ways. It also highlights the challenges that tropical cyclones pose to the well-being of the US population and underscores the central role that socioeconomic disadvantage plays in amplifying social vulnerability to hurricanes. The findings emphasize the importance of sound science to help inform policy and practice in promoting efforts to narrow cyclone-related mortality and health inequities in extreme events.

However, Parks et al[2] did not explicitly analyze climate change influences on hurricane mortality. Under the influence of climate change, Atlantic tropical cyclones are becoming stronger and wetter, and their translation speed (or speed of forward motion) tends to slow down as these systems move over coastal lands and encounter populated areas.[10-12] This combination of stronger, wetter, slower-moving storms is progressively generating climate-fueled storms that are more damaging, destructive, and deadly,[10-13] as could be more completely documented by extending the analytic approaches used by Parks et al.[2]

Moreover, the ongoing COVID-19 pandemic intersects with all concurrent extreme events. For instance, the risks of evacuating and sheltering populations in areas where COVID-19 was actively circulating during the record-setting 2020 Atlantic hurricane season in the prevaccine era have been described.[14-16] COVID-19 transmission risks were prominent again in 2021, despite vaccine availability, as Hurricane Ida affected Louisiana and Mississippi, 2 states with the lowest COVID-19 vaccination rates at the point when the summer Delta variant surge was peaking. It is likely that COVID-19 transmission occurred as families stayed together in homes or shared community congregate shelters. Some individuals who evacuated their homes during Ida may have developed severe COVID-19 and died or infected others who did not survive. In the complexity of superimposed risks, these COVID-19 deaths could also potentially be counted among tropical cyclone–associated deaths.

Moving forward, the approach described by Parks et al[2] should help contribute to improved official estimates of the broad scope of mortality associated with tropical cyclones as well as other natural hazards.

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With Sincere Thanks and Appreciation to *JAMA* Authors and Reviewers

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As a general medical journal, *JAMA* interacts with and serves numerous constituencies in medicine and health care, including authors, who provide content for the journal; peer reviewers, who assist in evaluation of the quality and validity of content; and readers, who use published content to expand knowledge and improve patient care. With the advent of the third year of the SARS-CoV-2 pandemic, we recognize and acknowledge many of the challenges that have affected and continue to affect these and other groups, including academic and practicing physicians, resident physicians and medical students, other health care professionals, as well as administrators, researchers, and public health officials. We express our deepest appreciation to and respect for the members of all these important groups and to many others in medicine and health care for their ongoing efforts in providing care for patients affected and not affected by COVID-19. We also express our appreciation to *JAMA* authors and reviewers for their contributions and support of the journal.

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In 2021, authors submitted 12 085 manuscripts to *JAMA*, including 7112 research reports (**Table**). We sincerely thank all authors who submitted for consideration for publication original research investigations, rigorous reviews, scholarly viewpoints, insightful editorials, and other manuscripts.

The quality, importance, and influence of the content in these manuscripts are reflected in *JAMA*'s current impact factor of 56.3 (based on 2020 information). Many authors submit manuscripts that are especially timely, such as research reports and viewpoints, that reflect the evolving nature of the SARS-CoV-2 pandemic; in 2021, manuscripts related to COVID-19 accounted for 44% of submissions to *JAMA*. Major studies and other articles have evaluated therapeutic interventions for COVID-19[1,2] and preventive interventions such as changes in effectiveness associated with COVID-19 vaccines as new SARS-CoV-2 variants have emerged.[3] Articles by authoritative authors have described timely updates on the dynamic clinical aspects of COVID-19[3-6] and have recommended new strategies and future approaches as the pandemic evolves.[7]

However, *JAMA* has continued to publish other important reports unrelated to COVID-19 that have immediate relevance and applicability to clinical practice. For instance, in 2021 *JAMA* published 32 reports from the US Preventive Services Task Force (USPSTF), including Recommendation Statements, Evidence Reviews, and other articles related to screening or interventions for common diseases and disorders. *JAMA* and the USPSTF have renewed this partnership to continue to publish this important content in *JAMA*.[8] In addition, a new ongoing series on Diagnostic Excellence provides thoughtful insights and scholarly perspectives on achieving excellence in this fundamental aspect of clinical practice.[9]

Evaluation of submitted manuscripts and decisions about publication are based on scientific quality, validity, and novelty;