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PROJECT REPORT

ASCERTAINMENT OF THE ESTIMATED EXCESS MORTALITY FROM HURRICANE MARÍA IN PUERTO RICO

IN COLLABORATION WITH THE UNIVERSITY OF PUERTO RICO GRADUATE SCHOOL OF PUBLIC HEALTH

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List of Acronyms

ASPR – Office of the Assistant Secretary for Preparedness and Response

BFS – Puerto Rico Bureau of Forensic Sciences

BTS – U.S. Bureau of Transportation Statistics

CDC – Centers for Disease Control and Prevention

CERC – Crisis Emergency Risk Communication

COE – Center for Operations in Emergencies

COOP – Continuation of Operations

DHHS – Department of Health and Human Services

DoH – Puerto Rico Department of Health

DPS – Puerto Rico Department of Public Safety

EMB – Puerto Rico Emergency Management Bureau

FEMA – Federal Emergency Management Agency

GAM – General Additive Model

GLM – Generalized Linear Model

GW SPH – The George Washington University Milken Institute School of Public Health

IRB – Institutional Review Board

NCHS – National Center for Health Statistics

NGO – Non-Governmental Organization

NIMS – FEMA National Incidence Management System

NPS – National Planning Scenario

PR – Puerto Rico

PRVSR – Puerto Rico Vital Statistics Registry

PRVSS – Puerto Rico Vital Statistics System

UPR GSPH – University of Puerto Rico Graduate School of Public Health

WHO – World Health Organization

EXECUTIVE SUMMARY

In order to accurately estimate the excess number of deaths due to Hurricane María, the Governor of Puerto Rico sought an independent assessment of mortality and commissioned The George Washington University Milken Institute School of Public Health (GW SPH) to complete the assessment.

The project had the following objectives: 1) assess the excess total mortality adjusting for demographic variables and seasonality, report a point estimate and confidence interval and make recommendations; 2) evaluate the implementation of Centers for Disease Control and Prevention (CDC) guidelines for mortality reporting in disasters and identify areas of opportunity for improvement; and 3) assess crisis and mortality communication plans and actions by the government as well as understand experiences and perceptions of key participant groups to make recommendations based on communications best practices.

METHODS

We implemented the project as three studies, each with specific yet complementary methodologies. Our excess mortality study analyzed past mortality patterns (mortality registration and population census data from 2010 to 2017) in order to predict the expected mortality if Hurricane María had not occurred (predicted mortality) and compare this figure to the actual deaths that occurred (observed mortality). The difference between those two numbers is **the estimate of excess mortality due to the hurricane.** We developed a series of generalized linear models (GLMs) with monthly data for the pre-hurricane period of July 2010-August 2017, accounting for trends in population size and distribution over this period in terms of age, sex, seasonality and residence by municipal level of socioeconomic development. Our estimates also considered Puerto Rico's consistently high emigration during the prior decade and dramatic population displacement after the hurricane. We used the model results to project forward mortality that would have been expected if the hurricane had not occurred for two scenarios–if the population had not changed **(census scenario)**, and explicitly accounting for massive post-hurricane population displacement from the island **(displacement scenario)**. For observed mortality, we used records for *all deaths occurring* from September 2017-February 2018, provided by the Puerto Rico Vital Statistics Records (PRVSR) division of the Puerto Rico Department of Health (DoH). The estimates of excess all-cause mortality attributable to the hurricane are the result of comparing the projections for the census and displacement scenarios to observed mortality in the vital registration data.

In order to respond to the Puerto Rican Government's query about how well CDC guidelines for mortality reporting in a disaster were followed, we conducted a two-part study to assess both the death certification process and the quality of death certificate data. We conducted interviews with 26 individuals involved in the death certification and registration process to understand procedures under normal conditions and whether and how these were affected after the hurricane. In addition, we reviewed legislation and manuals related to death certification in Puerto Rico, as well as literature on death certification in general and specifically in disasters. With respect to quality of the death certificates

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and coding for causes of death, we consulted the relevant scientific literature. We conducted a series of checks on the mortality dataset, assessing it for completeness, timeliness, internal consistency and the quality of cause of death reporting by evaluating garbage codes, or mis-assignments, in the underlying cause of death.

Our third study assessed crisis and emergency risk communications by the Government of Puerto Rico before and after Hurricane María, with an emphasis on the communications plans in place at the time of the hurricane, trained staff dedicated to crisis and emergency risk communication, procedures for mortality reporting to the public, spokespeople interaction with the media and key participant perceptions of the government's risk communication and mortality reporting. For the communication assessment methodology, instruments, and analytical framework, we applied established guidelines from CDC and the World Health Organization (WHO) for communication in emergencies, which are supported by a robust scientific evidence base. We also applied principles from the Federal Emergency Management Agency (FEMA) *Whole Community Approach* for community-based emergency preparedness (FEMA 2011). We interviewed 11 Puerto Rico Government agency leadership and communications personnel in order to understand: crisis and emergency risk communication plans, processes and interagency coordination for the preparation, approval and dissemination of information to the public; their experiences related to communications before and after Hurricane María; and recommendations for future communications in emergency situations. We also interviewed 22 key leaders from different communities in Puerto Rico, representing diverse stakeholder groups including municipal mayors, community and faith leaders, emergency responders, police, non-profit organization personnel, health care providers and funeral directors. In order to formulate recommendations for future communications, these interviews focused on understanding stakeholder experiences from Hurricane María, community involvement in disaster communications planning and perceptions of the government's risk communication and mortality reporting.

To assess the post-hurricane information environment, we reviewed 17 press releases and 20 press conferences from September 20, 2017-February 28, 2018 to evaluate information content and spokespeople performance, and to determine the extent to which trustworthiness, credibility and accountability were conveyed according to CDC and WHO guidelines. Finally, we analyzed 172 media coverage items from major English- and Spanish-language news outlets during the same time period, as well as related social media commentary, to identify factors that may have contributed to public concerns about mortality reporting, including: reasons and timing of mortality data reporting; contradictory information from spokespeople and alternative sources; information gaps; and perceptions of the accuracy and transparency of the Puerto Rico Government's mortality reports.

SUMMARY OF FINDINGS

a) Excess mortality estimation

We estimate that in mid-September 2017 there were 3,327,917 inhabitants and in mid-February 2018 there were 3,048,173 inhabitants of Puerto Rico, representing a population reduction by approximately 8%. We factored this into the migration "displacement scenario" and compared it with a "census scenario," which assumed no displacement from migration in the hurricane's aftermath. We found that, historically, mortality slowly decreased until August 2017, and that rates increased for the period of September 2017 through February 2018, with the most dramatic increase shown in the displacement scenario accounting for post-hurricane migration.

***Total excess mortality post-hurricane* using the migration displacement scenario is estimated to be 2,975 (95% CI: 2,658-3,290) for the total study period of September 2017 through February 2018.**

The results of our analysis of *total excess mortality by socio-demographic subgroups* show that every social stratum and age group was affected by excess mortality. However, the impact differed by age and socioeconomic status. The risk of death was 45% higher and persistent until the end of the study period for populations living in low socioeconomic development municipalities, and older males (65+) experienced continuous elevated risk of death through February. Overall, we estimate that 40% of municipalities experienced significantly higher mortality in the study period than in the comparable period of the previous two years.

We conclude that excess mortality is a good indicator for impact monitoring during and in the aftermath of a disaster.

b) Death certification process evaluation

Our study shows that physician lack of awareness of appropriate death certification practices after a natural disaster and the Government of Puerto Rico's lack of communication about death certificate reporting prior to the 2017 hurricane season limited the count of deaths that were reported as related to Hurricane María. Individuals authorized to complete death certificates include physicians and forensic physicians; however, most physicians receive no formal training in death certificate completion, in particular in a disaster. When asked about the CDC guidelines the PRVSR circulated after the hurricane that recommended physicians fill out a section in the death certificate with information or other conditions that contributed to the death, interview respondents indicated lingering confusion about the guidelines, while others expressed reluctance to relate deaths to hurricanes due to concern about the subjectivity of this determination and about liability.

The PRVSR offices sustained damage and did not have power to operate for some time after the hurricane, and death registration was delayed. Nevertheless, based on our findings in the assessment of death certification quality, the disaster does not appear to have affected the completeness of the certificates. For this assessment we compared Puerto Rico Vital Statistics System (PRVSS) data from September to December 2017 with the same period in 2015 and 2016 and found that *completeness* of death certificates was high with respect to age and sex, two indicators widely used to assess this aspect of mortality registration quality. On *timeliness,* there was a statistically significant delay in the number of days between date of death and date of death registration, with an average of 17 days in the period after the hurricane compared to 12 days in the prior year. Overall, there was a low percentage of garbage codes as the underlying cause of death and there appears to be *no impact from the event on the percentage of codes that were mis-assigned.* With respect to internal consistency, less than 1% of death certificates had medically inconsistent diagnoses in the underlying cause of death.

c) Assessment of Crisis and Mortality Communications and the Information Environment

According to interviews with Puerto Rico Government agency personnel, at the time of the hurricane, neither the Department of Public Safety (DPS) nor the Central Communications Office in the Governor's Office had written crisis and emergency risk communication plans in place. The DoH's Office of Emergency Preparedness and Response had an outdated emergency plan, including annexes for Risk Communication in Emergencies and Mass Fatality Management. Agency emergency plans that were in place were not designed for greater than Category 1 hurricanes, and risk messages conveyed to the public in preparedness campaigns were reported by key leaders to inadequately prepare communities for a catastrophic disaster. Key leader interview respondents also noted limited engagement of community stakeholders in strategic communication preparedness planning. Regardless, key leader interview participants described numerous strategic preparedness activities undertaken at the local level that they believed to minimize injuries and loss of life, especially for vulnerable populations.

According to Puerto Rico Government agency interviews, there were insufficient communication personnel at the time of the hurricane, and surge staffing was not adequately mobilized post-hurricane. Respondents reported a lack of formalized personnel structure for emergency communication functions, resulting in inadequate personnel and spokespeople training in crisis and emergency risk communication, deficiencies in coordination of communication between central and municipal governments and between central and federal government counterparts. Puerto Rico Government agency leadership interview respondents did not identify formalized protocols for the coordination and clearance of mortality reporting between the DPS and the DoH at the time of the hurricane.

Puerto Rico Government personnel and key leader interview respondents indicated that communication contingency plans were not in place to anticipate multiple cascading failures of critical infrastructure and key resource sectors. Consequently, the central government was not prepared to use alternative communication channels for health-related and mortality surveillance, public health information dissemination and coordination with communities, including radio and interpersonal communication. This contributed to delayed information availability, gaps in information and the dissemination of inconsistent information to the public. Furthermore, there were gaps in the information provided by the Government of Puerto Rico, including limited explanation of the death certification process, distinguishing between direct and indirect deaths, or explanations of barriers to timely mortality reporting. Despite the potential for information gaps to increase the risk of the propagation of misinformation and rumors, the Government of Puerto Rico did not systematically monitor and address misinformation or rumors in news outlets and on social media platforms. Efforts undertaken by outside groups to fill information gaps and identify hurricane-related deaths added to conflicting mortality reports in the information environment.

The inadequate preparedness and personnel training for crisis and emergency risk communication, combined with numerous barriers to accurate, timely information and factors that increased rumor generation, ultimately decreased the perceived transparency and credibility of the Government of Puerto Rico.

Key leader interview respondents perceived the death count to be much higher, and held viewpoints that government leadership was disconnected from the realities of Puerto Rican communities, that there was not transparency in reporting, that information was intentionally withheld to evade blame and that adequate systems were not in place to track the death count.

Our research identified the implementation of public information campaigns prior to the hurricane with public health and safety messages, but the messages did not adequately prepare Puerto Rican communities for a catastrophic natural disaster. There was limited community and stakeholder engagement in disaster communication planning, and ineffective communication contingency plans in place, resulting in limited public health and safety information reaching local communities post-hurricane and alternative communication channels that were not systematically utilized for disease surveillance and information dissemination.

RECOMMENDATIONS

OVERALL POLICY GOAL FOR MORTALITY SURVEILLANCE AND COMMUNICATIONS

To assure the capacity of mortality surveillance and crisis and emergency risk communication during natural disasters in Puerto Rico to support policies and interventions that protect life and health

RECOMMENDATIONS ON MORTALITY SURVEILLANCE FOR NATURAL DISASTERS

I. Strategic Objectives

To have a reliable and resilient institutional mortality surveillance process that provides trustworthy and accurate evidence during natural disasters to: Establish the magnitude of the impact of the disaster, identify areas and groups of highest risk, monitor the performance of public health protection and prevention, and inform policy-making and program implementation. These principles are recommended:

- Readiness, establish a routine process
- Rigorous, based on valid methods
- Timeliness, delivering on time
- Common good, having as a priority the welfare of all

II. Programmatic Recommendations for Natural Disaster Mortality Ascertainment

Development of an Organizational Agenda

- Develop a federal and Puerto Rico policy architecture for preparedness and response to major emergencies and natural disasters.
- Establish clear leadership of the DoH on mortality surveillance and capacity building of medical personnel on death certification.

- Assure complete staffing and professional capacity for the PRVSR and the Bureau of Forensic Sciences (BFS).
- Review the legal framework for DoH accountability, for medical facilities and physician assurance on death certification.
- Secure needed financial resources and reliable infrastructure with federal government support.

Establish an Excellence Program on Mortality Surveillance for Performance Monitoring

- Institute continuous mortality-based monitoring to assess disaster impact and the effectiveness of post-disaster interventions using the collaborations with UPR GSPH.
- Determine a quality improvement program for death certification with training for all physicians.

Establish a mechanism for continuous flow of surveillance results and interpretation to decision makers

- Improve efficiency and timeliness of flow of information to decision makers and engage stakeholders from civil society, the media and others.
- Ensure provision of feedback to those involved in the death certification process and in data analyses.

III. Recommendations for Future Advancement of Mortality Surveillance and Natural Disaster Preparedness

- Implement a cause-specific mortality analysis to establish causal pathways and identify priority areas
- Assess and strengthen public health functions.
- Evaluate the burden of disease related to mortality following Hurricane María.
- Advance the work on the analysis of small area statistics to identify heterogeneity within municipalities related to mortality from Hurricane María.
- Disseminate globally the experience gained by Puerto Rico in this major event.

RECOMMENDATIONS ON CRISIS AND MORTALITY COMMUNICATION IN NATURAL DISASTERS

I. Strategic Objectives

To use credible, transparent and effective crisis and risk communication during natural disasters as a mechanism for informing populations, protecting lives and instilling public trust. These principles are recommended:

- Preparedness, with planning as fundamental for effective crisis and emergency risk communication
- Credibility, as a critical factor for facilitating partnerships and protecting public health
- Transparency, as a mechanism for strengthening and informing decision-making
- Compassion, with acknowledgment and validation of individual and societal emotions and concerns

II. Programmatic Recommendations for Natural Disaster Crisis and Mortality Communications

Create an Integrated Puerto Rico Crisis and Emergency Risk Communication Plan and Planning Process

- Establish clear leadership by the Puerto Rico Emergency Management Bureau (EMB) and the Central Communications Office for the development of a Puerto Rico Crisis and Emergency Risk Communication Plan. Define roles, levels of engagement, and specific tasks for municipalities and all responsible agencies. Identify teams responsible for Plan updates at municipal, agency, and central government levels.
- Engage key stakeholders and local communities in the development of Crisis and Emergency Risk Communication Plans at municipal, agency, and Puerto Rico Government levels.

Coordinate and Build Capacity for Crisis and Emergency Risk Communication

- Coordinate the Puerto Rico Plan with Agency and Municipal Crisis and Emergency Risk Communication Plans.

- Establish an inter-agency committee to coordinate and oversee mortality surveillance clearance and reporting to the public in disasters, to include communications and technical experts.
- Formalize a network of municipal communication liaisons to facilitate the timely exchange of information with the central government pre- and post-disaster.
- Ensure expertise in emergency communication planning and management, crisis and risk communication, and mortality communication of government communication personnel from agencies responsible for public health and safety functions in disasters.
- Identify a cadre of official spokespeople for disasters, including subject matter experts.

III. Recommendations to Build Crisis and Mortality Communications Preparedness Capacity for Natural Disasters

- Update all Crisis and Emergency Communication Plans annually and following disasters.
- Provide crisis and emergency risk communication training for communications personnel, to include monitoring and addressing rumors and the effective use of social media in disasters.
- Implement media training for disasters with designated spokespeople.
- Conduct annual emergency communication exercises, including stakeholders and local communities.
- Develop a dashboard that characterizes current crisis and mortality communication capacity in disasters and tracks advancement over time for management and accountability.
- Conduct a KAP (knowledge, attitude and perception) population study to identify communication strategies, messages, key audiences, vulnerable groups, and communication channels in disasters.
- Disseminate broadly promising practices and lessons learned for community-based disaster.

INTRODUCTION

The Governor of Puerto Rico invited the George Washington University's Milken Institute School of Public Health (GW SPH) to submit a proposal (PR Gov 2018) to determine the excess mortality from Hurricane María.

The proposed study, titled "Ascertaining the Estimated Excess Mortality from Hurricane María in Puerto Rico," contained three components: a mortality assessment, an evaluation of the implementation of the Center for Disease Control and Prevention's (CDC) mortality reporting guidelines, and an assessment of crisis, emergency risk, and mortality communications.

In its overall approach to the commissioned project, the GW SPH agreed to produce a report with estimates of all-cause excess mortality associated with Hurricane María, the team proposed to: a) use vital registration data from September 2017 to February 2018 to estimate standardized mortality ratios relative to prior years, adjusting for age and sex composition of the population, as well as to produce a statistical model that would account for these factors and produce estimates of excess mortality for these months, including both point and confidence interval estimates of the excess all-cause mortality and a set of recommendations based on the findings; (b) evaluate the implementation of CDC guidelines for death registration during natural disasters and evaluate the quality of death certificate records before and after the storm to recommend improvements in these processes; and (c) review crisis and emergency risk communication plans and procedures in place before and after Hurricane María, interview participants and Government of Puerto Rico personnel to document how communication processes were implemented, analyze key issues and events, assess public perceptions of communications by the Puerto Rican Government, and provide recommendations best on best practices in disaster communications.

In addition to providing an accurate estimate of excess mortality after the storm, the GW SPH team also sought to inform the Government of Puerto Rico on the advantages of using mortality data for monitoring the conditions after a natural disaster. The study also assesses the government's challenges in death certification, classification, recording and reporting processes under normal circumstances and under the stress of a hurricane disaster. In the future, these results may be followed with an in-depth analysis of the cause-specific deaths directly and indirectly attributed to the hurricane. The communication component sought to identify challenges within the communications system as well as to recommend opportunities for addressing them. The communications component may also be followed by an in-depth assessment of communications capacity and processes, as well as the development of strategies to enhance public health communications during crises.

RESEARCH TEAM

The GW SPH established a research collaboration with the University of Puerto Rico Graduate School of Public Health (UPR GSPH) for project implementation. Other public and private institutions and individual experts within and outside of Puerto Rico were approached to collaborate on the project. Due to the level of confidentiality required for the project, as a first step, a secure environment was established for data storage and analysis. An interim report described much of the process to build the project, including institutional arrangements, establishment of the secure warehouse, and the collaborative environment (GW 2018).

Within the GW SPH, a multi-disciplinary team was assembled, consisting of epidemiologists, a demographer, a public health nutritionist, environmental health scientists, two public health research assistants, an anthropologist, a behavioral scientist and two health communication experts. An external expert review panelist from Johns Hopkins University joined the research team during the analysis of time-series of the mortality data set. The UPR GSPH team included three tenured faculty, including a biostatistician, an epidemiologist, and an epidemiologist with extensive experience in community research and a biostatistics research assistant (Annex 1 identifies the research members). They contributed methodological expertise, community research expertise and provided context for the GW SPH researchers on the Puerto Rico situation.

An expert review panel was established (Annex 2), with national and international experts in different fields, to review the methods at different project stages. Similarly, we had the support of a group of GW SPH global experts in medical humanitarian crisis

PURPOSE OF THE REPORT

The purpose of this report is to inform the citizens and the Government of Puerto Rico about the project's results. We believe the study findings will enhance the government's capacity to develop reliable mortality surveillance systems for hurricane disaster intervention and management and to implement efficient and robust public communication systems in the context of a natural disaster. The report also describes next steps in advancing a much-needed analysis on cause-specific mortality and in performing an assessment of the capacity for implementing public health functions that includes emergency surveillance and risk communication.

This report first presents project methods and findings and then proceeds to offer two sets of recommendations.

For more details on the methodology, data and programs used in the excess mortality calculations, these will be made available online at: http://prstudy.publichealth.gwu.edu/

MORTALITY

METHODS

Assessment of Excess Mortality

Excess deaths are deaths that exceed the regular death rate predicted for a given population (WHO 2018) had there not been a natural disaster or other unexpected or calamitous event, such as an epidemic or industrial accident (Geronimus et al 2004; Haentjens et al. 2010).

To estimate excess mortality associated with Hurricane María, it was necessary to develop counterfactual mortality estimates, or estimates of what mortality would have been expected to be had the disaster not occurred.

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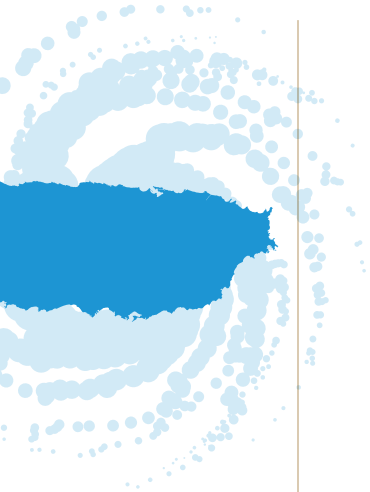
Using vital registration data from seven years prior to the storm, we defined two counterfactual scenarios for this analysis. The first, which we have labeled the 'census' counterfactual, assumes the rate of change in the resident population composition and distribution–both in terms of absolute size and factors associated with differential exposure to the risk of mortality (including age, sex and municipal socioeconomic development)[1] –remained unchanged after the hurricanes. The second scenario estimates cumulative excess net migration from Puerto Rico in the months from September 2017 through February 2018 and subtracts this from the census population estimates in these months. This is labeled the 'displacement' counterfactual. Comparing these counterfactual estimates of mortality over the period to that actually observed produces estimates of all-cause excess mortality. This excess can be represented as a count of excess deaths, or a ratio of the number of observed deaths to expected deaths had the hurricane not occurred.

Any estimation or comparison of mortality over time has to consider the population's age and sex distribution and seasonality. Similarly, it is important to take into account changes in population size. In the case of Puerto Rico we reviewed in- and out migration over the last decade and the net migration result was negative. The increase in out-migration has affected the population's demographics, and the storm accelerated this trend.

1. Age is categorized as between 0 and 39 years, 40 to 65 years, and 65 years and over. Sex is characterized as male and female. Municipal level socioeconomic development is defined as the tertiles (or equal thirds of the distribution) of the *Municipal Socioeconomic Development Index* (SEI), developed by the Puerto Rico Planning Board (Indice 2017). This measure captures the underlying strength of municipal level structural and institutional capacities.



To perform this analysis, we obtained vital registration mortality data including deaths by age, sex and municipality of residence from the Puerto Rico Puerto Rico Vital Statistics Registry (PRVSR) for the period July 1, 2010 to February 28, 2018. We derived baseline estimates of population size in each month from annual census estimates of population size by age, sex and municipality of residence. Cumulative monthly population displacement after the storm in each month was estimated using Bureau of Transportation Statistics (BTS) data on monthly net domestic migration provided by the Puerto Rico Institute of Statistics and a survey of airline travelers provided by the Puerto Rico Planning Board (Planning Board 2018).

The GW Institutional Review Board (IRB) granted the project human subjects exemption as it represented minimal risk. Data were transferred by the different government agencies through a secure, private Secure File Transfer Protocol (SFTP) and stored and managed in a protected environment certified against the HITRUST Common Security Framework (CSF) for HIPAA compliance and meeting the FIPS 140-2 standard.

We began our analysis with descriptions of age-standardized mortality rates, age-specific rates and rates by level of municipal socioeconomic development after the storm relative to previous years. To estimate counterfactual mortality under the census and displacement scenarios, we developed a series of generalized linear (GLM) overdispersed log-linear regression models using the historical registration data from July 2010 to August 2017. These models account for trends in population size and distribution over this period in terms of age, sex and residence by municipal-level socioeconomic development. We used the model results to project forward mortality that would have been expected if the storm had not occurred and the population had not changed (the census scenario), and explicitly accounting for the massive population displacement away from the island occurring during this period (the displacement scenario). Comparing these projections to observed mortality in the vital registration data, we arrived at our estimates of excess all-cause mortality attributable to the storm. In addition to the GLM models, we estimated a Generalized Additive Model (GAM) using the same data as a robustness check on the GLM results. The GLM and GAM models make different assumptions and treat the data differently, including in the specification of overdispersion, autocorrelation and long-term and seasonal trends.

To provide context for our results, we have also replicated the analyses of others who have attempted to estimate excess mortality in the post-María period, comparing their estimates and their methodologies to those used here.

Death Certification Process

This study evaluated the implementation of the CDC procedures for mortality registration in the aftermath of the hurricanes in Puerto Rico following the CDC evaluation protocol, *Updated Guidelines for Evaluating Public Health Surveillance Systems* (German 2001).

The team generated information on (a) processes and procedures of death certification, classification and registration in Puerto Rico, and (b) participants involved in each process. Through this initial research, the team identified all sources with the authority for completing the death certification and registration process as well as the relevant institutions and sectors (public and private) responsible for carrying out each process. Researchers targeted individuals within specific institutions for interviews and identified areas for conducting site visits.

Participants in the death certification process are the persons or organizations that certify the occurrence of a death, generate, use or otherwise attest to deaths, mortality registration and/or generate mortality data. For the death registration assessment, potential interviewees included: physicians, PRVSR staff, funeral home directors, hospital directors, forensic pathologists, Federal Emergency Management Agency (FEMA) personnel and members of key associations. We chose interviewees from different municipalities in Puerto Rico.

The interview guides were tailored to each participant group and informed consent forms were developed. Spanish and English-language interview guides and informed consent forms were approved by GW IRB and UPR GSPH. Each interview guide described: 1) the regular processes, 2) organization or agency policies, and 3) changes in processes during and after Hurricane María. Our team field-tested the interview guides in Puerto Rico; and also reviewed manuals for certification and registration of deaths produced by the Puerto Rico Demographic Registry, Puerto Rico laws pertaining to death registration, and several sets of guidelines from CDC and National Center for Health Statistics (NCHS) on certification of deaths in disasters (Department of Health (DoH) 2015a; DoH 2015b; CDC ND, CDC 2017).

Upon obtaining IRB authorization, our team traveled to Puerto Rico to conduct interviews – 26 in a two-week period. All interviewees received an informed consent form. To compare Puerto Rico death certification procedures with those of the US mainland, we used the same interview guide with a person from a local health department on the mainland that historically had been affected by a major hurricane. The interviews were audio-recorded using a secure device. Once transcribed, the recordings and transcriptions were placed in Armor, the secure platform used by the project to store sensitive data.

Death Certification Data Quality

Studies have established that the quality of death certificate data are affected by the individual completing the certificate, availability of decedents' health records and the vital statistics systems' architecture where the data are entered, analyzed and reported. Several studies have highlighted the inherent subjectivity stemming from individuals who complete the death certificate; these studies document differences in death-cause attribution of the same patients between physicians and within and between medical specialties. For individuals who have no readily available or updated health records, physicians often have to rely on the acute events leading to the death. In the US, the NCHS reviews all death certificate data and applies algorithms to make the final determination of underlying cause of death and sequence of events that led to the death. Typically, these are automated, with roughly 15% of death certificates being manually coded.

One purpose of this analysis was to assess the quality of death certificate data after Hurricane María compared to the two previous years.

The team analyzed death certificate data quality to formulate recommendations that would improve death certification procedures during and after a disaster.

We followed standard approaches to assess the quality of the mortality registration process (Naghavi 2010, World Health Organization (WHO) 2013, Philips 2014). The indicators we used were: percent of garbage codes as underlying cause of death, percent of missing age or sex, percent of medically implausible diagnoses and average number of causes of death reported per person per specified time period.

Data

We obtained vital registration mortality data including deaths by age, sex and municipality of residence from the PRVSR for the years 2015 through 2017.

Mortality Registration Quality

Cause of death reporting/garbage codes: Mis-assignment of the underlying cause of death was calculated using a combination of the methods described by Naghavi (2010) and Philips et al. (2014) and by WHO (2013) and comparing both. Garbage codes refer to diagnoses that should not be considered as an underlying cause of death or assigning deaths to causes that are not useful (Naghavi 2010). Garbage codes were classified into: Type 1, codes without any inherent information about the underlying cause of death (e.g., heart beat abnormalities, dizziness); Type 2, codes that describe intermediate causes of death (e.g., heart failure, septicemia, or pulmonary embolism); Type 3, codes that represent immediate causes of death that are the final steps in a disease pathway leading to death (e.g., cardiac arrest, respiratory failure); and Type 4, unspecified causes

within a larger cause (e.g., unspecified bacterial infection, metabolic disorder). Several experts meet on a regular basis to revise the definitions of these groupings. We used the expanded 1 to 4 garbage coding definitions from Philips et al. (2014) and personal communication. We also calculated garbage codes as defined by WHO.

Completeness of age and sex: To assess quality of age and sex reporting, we calculated the number of deaths with unspecified date of birth, age, sex or a combination of these as a fraction of all deaths reported.

Internal consistency: Following the procedures used by Philips et al. (2014) and by WHO (2013), we calculated the number of implausible cause of death assignments for any given age or sex. For example, females diagnosed with testicular or other male reproductive-organ cancers, males with obstetrical conditions, pregnancy-related mortality for males or for females under age 10.

Timeliness: This indicator refers to timeliness on many levels. For this analysis, researchers calculated the number of days between date of death and date of registration and assessed whether delays were related to the hurricane.

Number of causes of death reported: We calculated the number of causes of death assigned for each decedent and then calculated the average in each of the specified time periods to assess whether this was impacted by the event.

We assessed statistical significance using t-tests, chi-square tests, and simple linear regression models, as appropriate (Suárez, 2017).

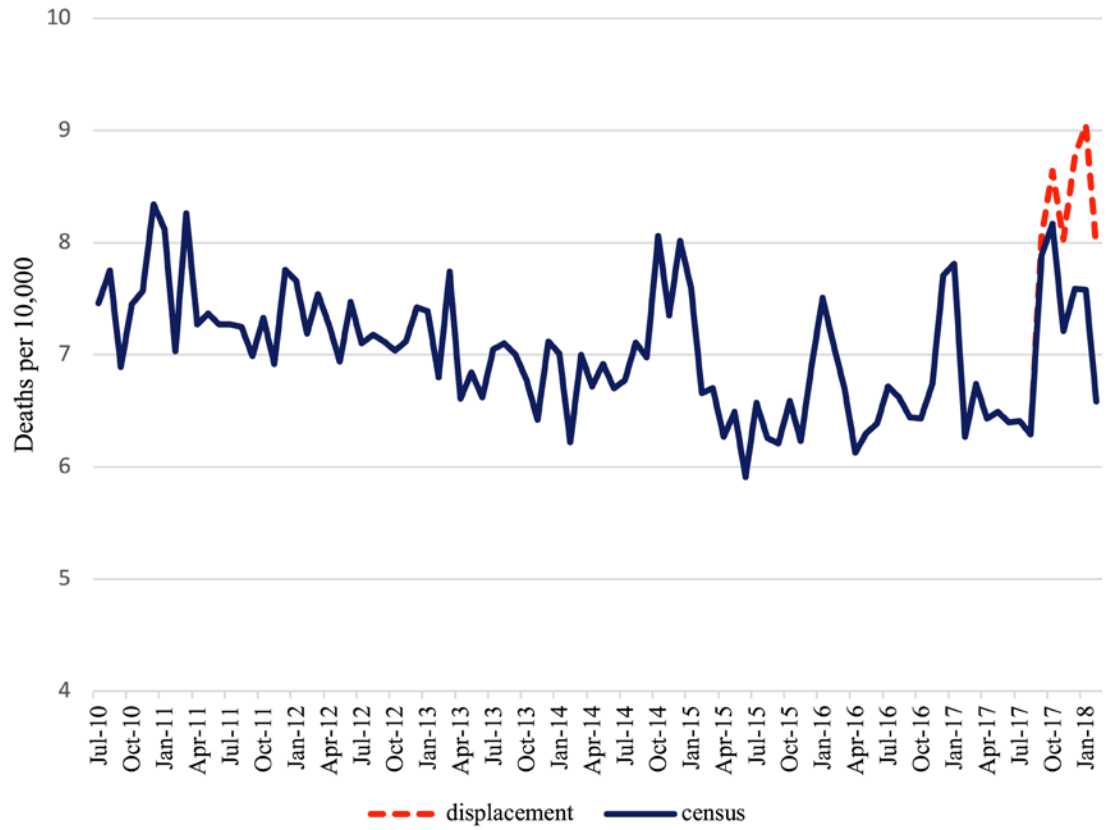
FINDINGS

Ascertainment of Excess Mortality

The PRVSR documented 16,608 deaths from September 2017 to February 2018–9,054 males and 7,554 females. Approximately 77% were older adults (65+ years), and 18% resided in the municipalities with low socioeconomic development. We estimated that in mid-September 2017 there were 3,327,917 inhabitants and in mid-February 2018 this number was 3,048,173 inhabitants of Puerto Rico, a total population reduction of approximately 8%. This was factored into the migration "displacement scenario" and compared with the "census scenario."

Age-adjusted mortality rates for Puerto Rico tend to be higher in the winter and early spring, declining in the summer months (Figure 1). Mortality has been slowly declining from 2010 on, but increased markedly in the period after September 2017, most dramatically under the displacement scenario accounting for migration after the hurricane.

Figure 1. Age-Standardized Monthly Mortality by Year (per 10,000 inhabitants), Puerto Rico, 2010-2011 to 2017-2018. U.S. Census and Displacement Scenarios for 2017-2018



Results from the preferred statistical model, shown below, estimate that excess mortality due to Hurricane María using the displacement scenario is estimated at 1,271 excess deaths in September and October (95% CI: 1,154-1,383), 2,098 excess deaths from September to December (95% CI: 1,872-2,315), and, 2,975 (95% CI: 2,658-3,290) excess deaths for the total study period of September 2017 through February 2018.

Table 1 shows observed, predicted and excess mortality by month for the study period as well as the total study period.

Table 1. Observed, Predicted and Excess (95% CI) Mortality, Puerto Rico, September 2017 to February 2018, Model 3, Displacement Scenario

	SEPT-OCT 2017	SEPT-DEC 2017	SEPT 2017-FEB 2018
OBSERVED	5,921	11,375	16,608
PREDICTED	4,650	9,277	13,633
EXCESS	1,271	2,098	2,975
95% CI	(1154, 1383)	(1872, 2315)	(2658, 3290)
OBSERVED/PREDICTED	1.27	1.23	1.22

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Every social stratum and age group was affected by excess mortality, however, the impact differed by age and socioeconomic status (Figures 2 & 3). Risk of death was higher and persistent until the end of the study period for populations living in low socioeconomic development municipalities (a ratio of 1.5 at the end of February 2018). Older males (65+) experienced continuous elevated risk of death through February, while most other groups approach the baseline mortality risk at 2 and 4 months post-hurricane, and all do so by February.

Figure 2. Estimated Relative Excess Mortality from Hurricane María in Puerto Rico, Per Month, by SEI Category

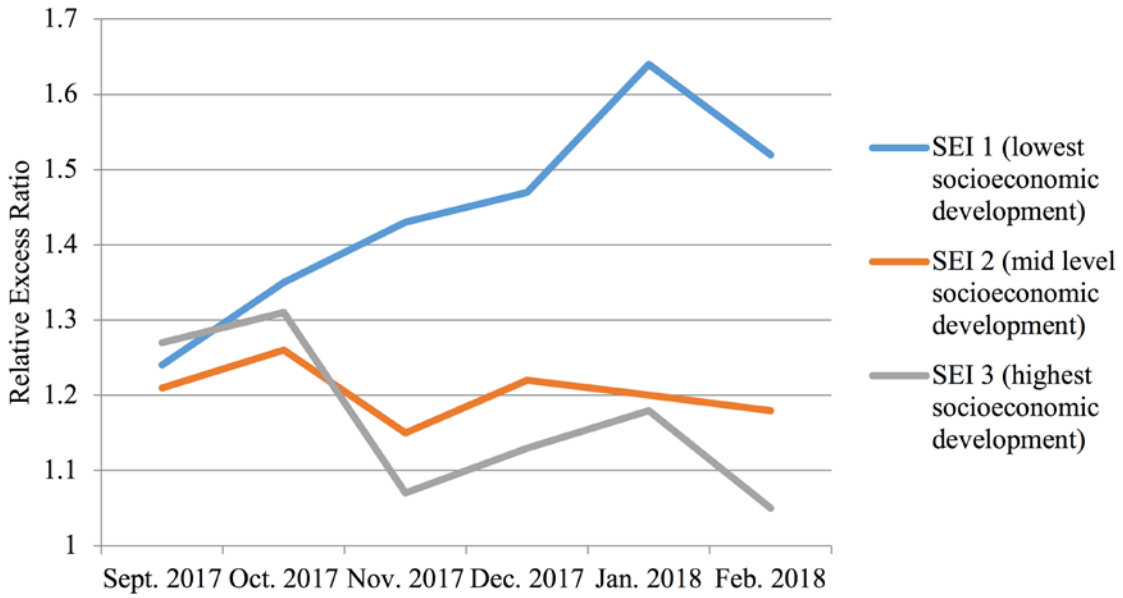
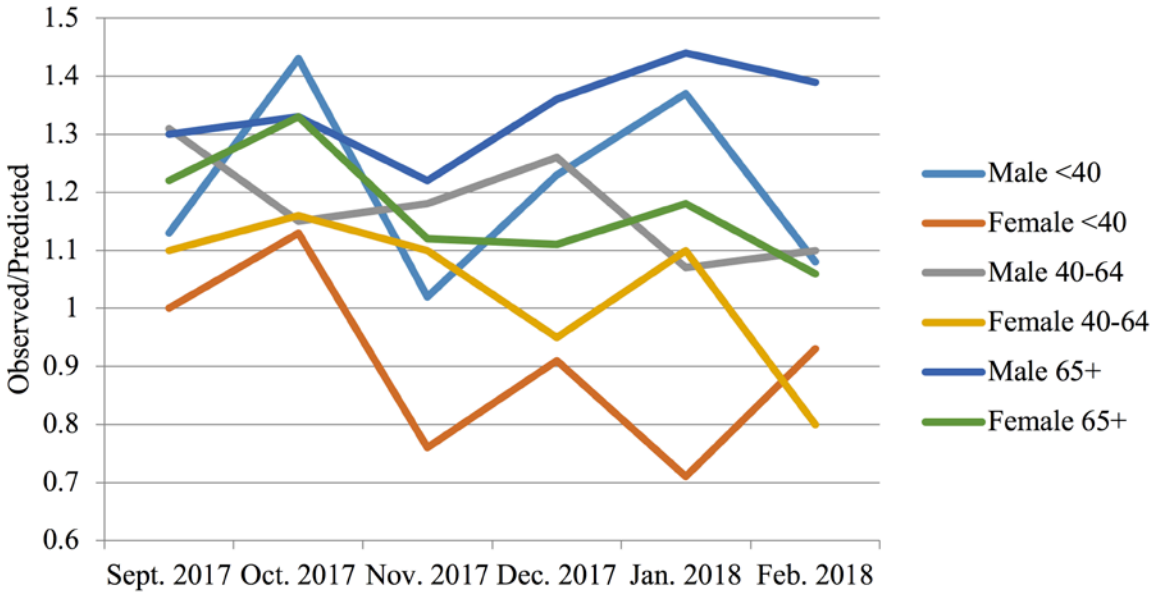
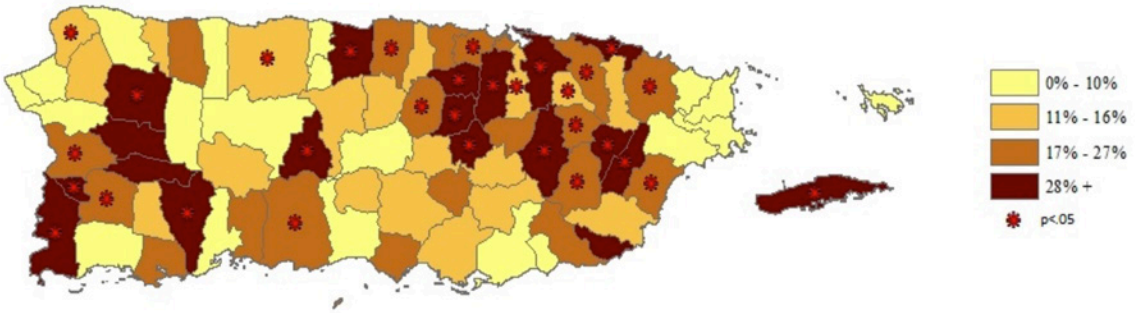


Figure 3. Estimated Relative Excess Mortality from Hurricane María in Puerto Rico, Per Month, by Sex and Age Group



No areas of the island were unaffected, but in its aftermath, some municipalities suffered greater increases in mortality. Figure 4 displays the estimated percentage increase in the crude mortality rates by municipality (not accounting for age distribution differences) for the period inclusive of September-February 2017-18 relative to the average rate in the same period in 2015-16 and 2016-17 under displacement scenario. **Significant differences between these two periods are denoted with asterisks.** As can be seen from this figure, the largest mortality differentials are concentrated in the northeast, and to a lesser extent, southwest portions of the island. Overall, however, approximately 40% of municipalities saw significant increases in mortality during the study period than in the comparable period of the previous two years.

Figure 4. Estimated percentage increase in crude mortality rates by municipality in Puerto Rico from September 2017-February 2018.



The official government estimate of 64 deaths from the hurricane is low primarily because the conventions used for causal attribution only allowed for classification of deaths attributable directly to the storm, e.g., those caused by structural collapse, flying debris, floods and drownings (see below). During our broader study, we found that many physicians were not oriented in the appropriate certification protocol. This translated into an inadequate indicator for monitoring mortality in the hurricane's aftermath. Verification of attribution takes time, while excess mortality estimation is a more immediate indicator.

Death Certification Process

The analysis shows that physician unawareness of appropriate death certification practices after a natural disaster and the Government of Puerto Rico's lack of communication about death certificate reporting prior to the 2017 hurricane season substantially limited the count of deaths related to María.

Based on a review of scientific literature, laws and manuals, as well as interviews on the death certification and registration processes in Puerto Rico, we established that the persons authorized to complete death certificates include physicians and forensic physicians. Most physicians have no formal training in completing a death certificate and thus are not aware of appropriate death certification practices, especially in a disaster setting. When the special CDC guideline was disseminated after the disaster, some of those who had access to it found that it conflicted with what they had previously learned. Those interviewed said they did not receive information about how to certify deaths during, or in conditions created by, a disaster. Several interviewed physicians were asked about the CDC guidelines the PRVSR circulated after the hurricane that recommended they fill out a section in the death certificate with information or other conditions that contributed to the death. Several said– as did a spokesman for the physician community in hearings–that they understood this section as seeking more information about health conditions. A few interview respondents indicated some reasons for reluctance to relate deaths to hurricanes, including concern about the subjectivity of this determination and about liability.

There was also a communication problem between the PRVSR and other government agencies and participants in the death certification and registration process, physicians, funeral home directors, hospitals and the organizations that represent them (e.g., the College of Physicians and Surgeons of Puerto Rico and the Association of Hospitals of Puerto Rico). Many stated that the Puerto Rico Department of Health (DoH) and the Puerto Rico Department of Public Safety (DPS) did not notify them about the CDC special guidelines for correct documentation of cases, on the importance of correctly documenting deaths related to the hurricane or on an emergency protocol for handling these cases.

Death certification and registration processes in Puerto Rico were affected by Hurricane María. The PRVSR offices sustained damages and did not have electric power to operate immediately after the hurricane. Even for the offices which had generators, the electronic system used was not always operational. PRVSR leadership re-deployed staff to offices that were still operational and to San Juan so that, at the very minimum, staff could receive information and begin processing the deaths. Because the agency's electronic system was offline, everything was done on paper, and all certificates were collected by supervisors and taken to San Juan for quality review and data entry. This resulted in delays in death registration, ranging anywhere from 7-10 days to 17-27 days. Based on a concurrent study of quality of the death certificate data, it does not appear to have affected the completeness of the certificates (see death certification quality).

Once operations resumed, the PRVSR personnel tracked the data coming in. When they saw that the numbers of death per day were considerably higher than normal, which is about 75 deaths per day, they began checking death certificates and found that those relating the deaths to the hurricane were scarce. The PRVSR sought to disseminate the CDC guidelines to participants in the certification process (physicians, hospitals, funeral home directors, etc.)

PRVSR personnel indicated they provided the information to the different groups via email, through the weekly meetings at the government Center for Operations in Emergencies (COE), as well as through interviews with the press.

According to PRVSR personnel, a very small number of those completing death certificates did relate the deaths to the hurricane. Most other certificates lacked such information. This reduced the number of death certificates that indicated a relationship with the hurricane.

As part of this study, the team also interviewed individuals involved in death certification in mainland states and at the NCHS. According to these respondents, the quality of mortality data is affected by how much the person filling out the death certificates knows about this task

The lack of training on death certificate completion is also a problem on the mainland, and several jurisdictions have sought to remedy this deficiency by creating and requiring training courses on death certification for physicians and other personnel responsible for completing death certificates. NCHS has developed an e-course as well. To date, there are no formal courses on death certification in natural disasters for persons who fill out death certificates.

Several laws govern the certification of death in Puerto Rico, including the laws that set up the PRVSR, the Puerto Rico Bureau of Forensic Sciences (BFS), as well as the law for Funeral Homes (*Ley del Registro General Demográfico de Puerto Rico,* 1931; *Ley para declarar la muerte en caso de eventos catastróficos,* 1985; *Ley del Departamento de Seguridad Pública de Puerto Rico,* 2017;). In addition, the PRVSR has created instruction manuals, available online, for filling out death certificates (DoH 2015_a; DoH 2015_b). Nevertheless, none of these laws or manuals address death certification during disasters. A low impact of federal guidance to support mortality-surveillance disaster planning both at the BFS and PRVSS was identified.

Death Certification Quality

We compared PRVSS data from September 2017 to December 2017 with the same period in 2015 and 2016. In addition, we compared the period from September 20 to September 30 in each of the 3 years.

Mortality Registration Quality

Cause of death reporting/Garbage codes: Table 2 shows the trends in Types 1-4 garbage codes from 2015-2017. Overall, about 20% of the PRVSS records had garbage codes of at least one type as the underlying cause of death over the study period. However, there was a statistically significant increase in Type 1 and Type 2 garbage codes in the period following Hurricane María compared to the same period in the prior year. There was no difference in the percentage of Type 3 and Type 4 garbage codes following Hurricane María

Table 2. Percent of Garbage Codes as the Underlying Cause of Death by Type and Year from 2015-2017

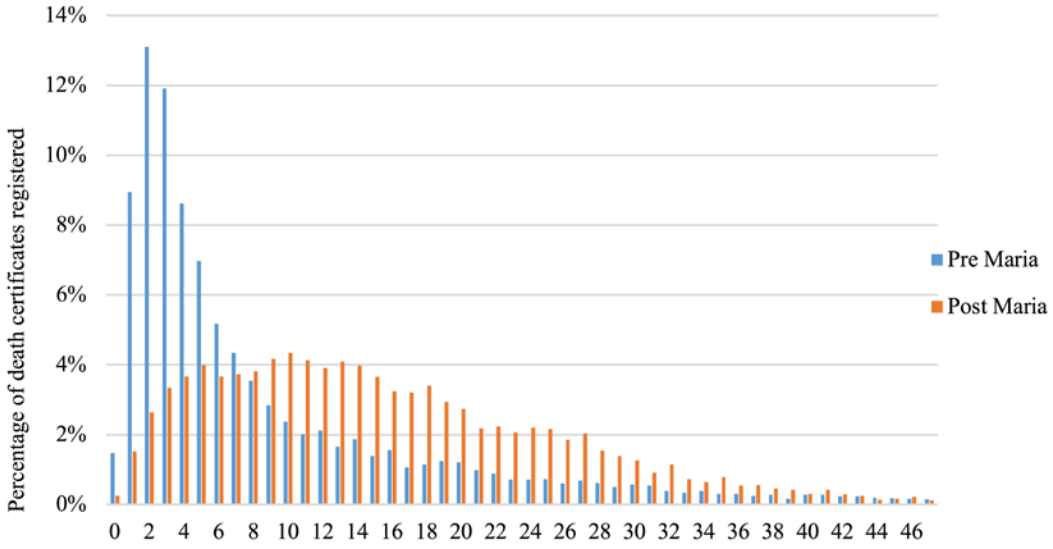
YEAR	TYPE 1 GARBAGE CODES (%)	TYPE 2 GARBAGE CODES (%)	TYPE 3 GARBAGE CODES	TYPE 4 GARBAGE CODES
2015	20.1	4.1	3.9	6.5
2016	20.1	3.1	4.3	5.8
2017	23.6	6.3	3.8	6.3

Completeness of age and sex: Completeness of death certificate quality was high with respect to age and sex, which are two indicators widely used to assess mortality registration quality. Less than 0.1% of records had missing age or sex. There was no statistically significant association between the event and completeness of age or sex data.

Internal consistency: With respect to internal consistency, less than 1% of death certificates had medically inconsistent diagnoses in the underlying cause of death as defined by Philips et al. (2014), and there was no statistically significant association between the event and internal consistency.

Timeliness: There was a statistically significant delay in the number of days between date of death and date of death registration, with an average of 17 days in the period after the hurricane compared to 12 days in the prior year. Figure 5 shows the percentage of certificates per day processed for the pre-María period of September-December 2016, compared to the same period in 2017.

Figure 5. Length of Time (In Days) between Date of Death and Date of Registration of Death (Timeliness) before (September-December 2016) and after Hurricane María (September-December 2017)



Number of causes of death reported: There was a statistically significant decrease in the number of causes of death listed on a death certificate after the hurricane, with about 47% of death certificates listing two or more causes of death in 2016 compared to 44% in 2017.

The results presented herein highlight overall improvements that were made to Puerto Rico's death registration system over the four years prior to Hurricane María, as evidenced by low rates of garbage codes, completeness in age and sex recording, high rates of internal consistency and improvements in timeliness. Following Hurricane María, there was a slight, although statistically significant, increase in the percentage of Type 1 and Type 2 garbage codes. This is in line with our findings from the assessment of the death certification process in the previous section that described biased coding of death certificates in response to inadequate health infrastructure. As stated in the previous section, the time from date of death to registration also increased significantly following the hurricane. This also corroborates the results of our qualitative assessment.

RECOMMENDATIONS

OVERALL POLICY GOAL FOR MORTALITY SURVEILLANCE AND COMMUNICATIONS

To assure the capacity of mortality surveillance and the communication of its results to support policies and interventions for the protection of people´s life and health during crises produced by natural disasters in Puerto Rico

RECOMMENDATIONS ON MORTALITY SURVEILLANCE FOR NATURAL DISASTERS

I. Strategic Objectives

To have a reliable and resilient institutional mortality surveillance process that provides trustworthy and accurate evidence during natural disasters to:

- Establish the magnitude of the disaster's impact
- Identify areas and groups of highest risk
- Monitor the performance of public health protection and prevention
- Inform policy-making and program implementation

We recommend the following guiding principles:

- Readiness: establish a routine process
- Rigor: based on valid methods
- Timeliness: delivering on time
- Common good: having as a priority the welfare of all

II. Programmatic Recommendations for Natural Disaster Mortality Ascertainment

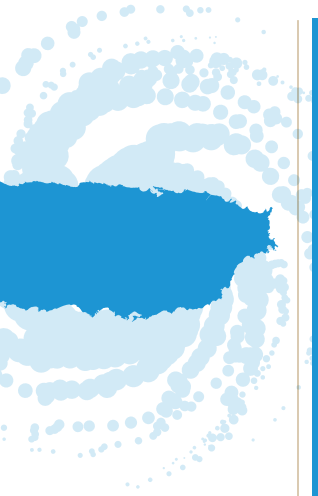
A. Development of an Organizational Agenda

Develop a federal and Puerto Rico policy architecture

- Establish a planning process for hurricane disasters with overall responsibility under the Office of the Governor.
- Update the Public Health and Medical Situation Awareness Strategy 2014 to consider surveillance needs for states and territories and provide effective guidance for the specificities of natural disasters (DHHS, 2015).
- Create a culture of preparedness and planning at the federal and Puerto Rico levels, including collaborative data-sharing and monitoring during the emergencies.

Define clear leadership

- Under all circumstances, the Puerto Rico DoH has responsibility for all population mortality surveillance. The DoH has the power of legal attribution, it is the counterpart to the federal governmental and international agencies that address these issues, and it has to be able to use the surveillance mechanism for effective and timely intervention.
- Within the DoH, the PRVSR has to be the official site for integration of such information; this office collects statistical data and is responsible for analysis. The information produced by the PRVSR should be integrated with the DoH surveillance system. This integration should be established by administrative order.
- The DoH needs to be consulted in policy-making discussions and set norms and guidance on mortality certification during emergencies.



Assure strong professional capacity

- Train public health professionals in public health preparedness. We recommend that the Schools of Public Health of Puerto Rico and the continental US establish programs in this field to advance Healthy People 2020 goals (CDC 2013).
- Assess public health capacity to effectively implement public health functions within Puerto Rico, including mortality surveillance.
- Train personnel to manage mortality surveillance at the local and central levels of the PRVSR.
- Fully staff the PVRSS for key positions with graduate degrees in demography and other public health disciplines (e.g., biostatistics, epidemiology, data management).
- Complete the staffing at the BFS. Surge planning should call for additional personnel beyond a fully staffed organization.

Review the legal framework

- Define the Puerto Rican DoH's accountability and review the legal basis supporting the attribution of responsibilities between the DoH and DPS on the topic of mortality surveillance and reporting.
- Protect medical personnel from consequences of certifying the circumstances of a death in a natural disaster. A legal framework should also protect medical facilities in fulfilling their mandates for certification.
- Establish a legal agreement for the continuous information transference and updating to the DoH for mortality surveillance with the BFS, the Census Bureau and the Puerto Rico Institute of Statistics.

Assign needed financial resources and secure reliable infrastructure

- Assure the integrity, completeness and resilience of strategic sites, the PRVSS and the BFS, with, for example, reliable electrical power, safety installations, redundancy systems, backups, transportation and alternative telecommunication capabilities. Put in place Continuity of Operations (COOP) plans.
- The federal government should support the implementation of this agenda and its financing. An executive order should be issued for an expansion of the regular operating budget to all organizations and especially the DoH, BFS, PRVSR.

B. Establish an Excellence Program on Mortality Surveillance for Performance Monitoring

Use mortality-based monitoring to assess disaster impact and the effectiveness of interventions in the aftermath

- Establish a continuous surveillance system based on the principle of transparency, staffed by PRVSR and DoH professionals. The system can be used as a public health tool for systematic analysis and interpretation of total all-cause deaths.
- Develop specific indicators and special monitoring of vulnerable groups (low SEI and older adults).
- Establish collaborations of the UPR GSPH with the government and, particularly, the DoH for staffing and for students' professional development, laying foundations for a Center of Excellence.
- Differentiate between terms. Use the term *hurricane (or other natural disaster event) excess death* as the indicator to track and identify departures from predicted/expected mortality. It should use *hurricane-attributable mortality* for confirmed cases to both monitor and certify death.
- Establish a system of continuous modeling of mortality trends using the models provided, with constant updates of sociodemographic information.
- Allow for recovery monitoring in the system and define the scope and duration of remediation interventions by federal and territorial governmental and social agencies.

Establish a continuous quality improvement program for death certification

- Continuously measure indicators and establish a monitoring system, particularly when changing to the e-certification system. Include a continuous measurement of indicators on death certification quality in the monitoring system. Make this information available to the medical community at all times.
- Train all medical doctors on death certification. Use existing, publicly available online courses by Pan-American Health Organization (PAHO) or NCHS. Ensure this training is a requirement of College of Physicians and Surgeons for medical accreditation.
- Implement collaborations of the DoH and the BFS with universities such as UPR GSPH to train personnel on quality improvement and in-depth studies of death certification.

C. Establish a Mechanism for Continuous Flow of Analysis and Interpretation of Results to Decision Makers

Improve efficiency of flow of information to decision makers

- Design instruments to convey results in a timely manner to key decision makers during a natural disaster. Engage stakeholders from civil society, the media and other groups.
- Base decisions on evidence from the continuous monitoring system and its indicators.

Ensure provision of feedback to those involved in the death certification process

- Convey results in a timely manner to those generating them, such as medical doctors.
- Develop instruments to effectively and efficiently communicate with these target groups as part of establishing a surveillance system with a bidirectional flow of information.

III. Recommendations for the future advancement and in preparation for other potential natural disasters

- Analyze cause-specific mortality to establish causal pathways and identify priority areas (see Annex 3).
- Assess and strengthen public health functions at the DoH.
- Evaluate the burden of disease related to mortality from Hurricane María.
- Advance the work on the analysis of small-area statistics to identify the heterogeneity within municipalities in the mortality experience from Hurricane María.
- Disseminate globally the experience gained by Puerto Rico in this major event.

COMMUNICATIONS

METHODS

Assessment of Crisis and Mortality Communications and the Information Environment

The current study includes an assessment of disaster and/or communications planning and actions taken by the Puerto Rican Government before and after Hurricane María, with an emphasis on the plans in place at the time of the hurricane, the number of trained staff dedicated to crisis and emergency risk communication, spokespersons' interaction with the media and stakeholder perceptions of the government's risk communication and reporting of mortality. The communication assessment methodology, instruments and analytical framework were informed by established guidelines and principles, which are supported by robust scientific evidence detailed in: 1) CDC's *Crisis Emergency Risk Communication* (CERC) manual (CDC 2014), 2) WHO's *Communicating Risk in Public Health Emergencies* guidelines (WHO 2017), 3) WHO's *Effective Media Communication During Public Health Emergencies* handbook (WHO 2005) and 4) FEMA's *A Whole Community Approach to Emergency Management* (FEMA, 2011).

Government Personnel and Key Leader Interviews: Two bilingual GW SPH researchers conducted 33 interviews from April-June, 2018. Eleven interviews were conducted with Puerto Rico Government agency leaders and communication personnel, and 22 with key leaders representing different stakeholder groups, described more below.

Puerto Rico Government personnel interview participants were identified based on their role in overseeing government communications personnel, or in coordinating, developing, approving and/or disseminating public health, public safety or mortality information to the public. We interviewed government agency personnel to gain their perspective on planning and actions related to crisis and public health communications during the pre- and post-hurricane periods.

Government personnel recruited for interviews included agency leaders; press/communications directors; a demographer with involvement in vital statistics data management; a health-related program director; and a risk communication analyst. Interview guides inquired about the following topics: the agency's role in public health communication and/or mortality reporting, including communication during an emergency; communication plans or other processes for the preparation, approval and dissemination of information to the public; target audiences for communication; inter-agency collaboration; communications experiences related to Hurricane María; and recommendations for future communications.

We selected key leader interview participants to represent diverse segments of society or broadly defined stakeholder groups. These interviews were meant to understand the range of experiences from Hurricane María, involvement in disaster planning and communications among leaders in various communities around the island as well as their perceptions of the government's risk communication and mortality reporting.

These interviews were conducted within a sample of Puerto Rico municipalities, which were selected to obtain a sample with diversity according to the following criteria: geographical distribution; regional representation; socioeconomic status; predominant political affiliation; demographics; and proximity to hospitals/clinics. Interview participants included: municipal mayors, community leaders, emergency management staff, police, a faith leader, health care providers, non-profit organization staff, and a funeral director. The key leader interview guide focused on the following areas: experiences related to Hurricane María; perceptions of mortality reporting and reassessment; risk-communication information received; recommendations for future communications; and identification of target audiences, optimal channels and community outreach strategies for information dissemination.

All interviews were audio-recorded using a secure device. The Spanish-language transcripts were analyzed using qualitative data analysis methodology, which entails reviewing transcript text, identifying where specific topics are discussed, tagging that text with codes that represent particular themes, summarizing responses by theme and then conducting thematic analysis. From this systematic process, researchers identified areas of consensus and discord among participants, which facilitated the characterization of experiences and perceptions. The interviews were analyzed in accordance with guidelines outlined in the documents identified above.

Press Releases and Press Conferences: Three GW SPH researchers with expertise in public health communications, risk communication and media systematically reviewed official press releases the Governor's Office disseminated and press conferences from September 20, 2017-February 28, 2018. These information sources were examined to identify key messages for hurricane-related mortality reporting to evaluate information content, the manner in which information was delivered and spokespeople performance.

GW SPH sought to determine the extent to which trust, credibility, transparency and accountability were communicated, according to criteria specified in WHO's *Effective Media Communication During Public Health* and *Steps of Communication in Crisis Emergencies* (WHO, 2017) and the CDC CERC manual guidelines (CDC, 2014).

We reviewed 17 press releases provided by the Governor of Puerto Rico's Central Communication Office and 20 press conferences, 10 of which were transmitted via the governor's Facebook account and 10 of which were provided in audio recording format.

Digital Media Coverage & Social Media Commentary: Three GW SPH researchers with expertise in public health communications, risk communication and media compiled and reviewed media coverage from major English- and Spanish-language news outlets pertaining to hurricane-related mortality reporting, as well as related social media commentary from September 20, 2017-February 28, 2018 in order to identify factors that may have contributed to public concerns about mortality reporting. We reviewed 172 digital media news stories and related social media posts. We analyzed these information sources to identify the following: reasons and timing of the dissemination of mortality data, contradictory mortality data from Puerto Rico Government spokespeople and alternative sources, information used to consider a death as hurricane-related, information gaps filled by non-official information and perception of the accuracy and transparency of the Puerto Rico Government's messages about death figures.

FINDINGS

Assessment of Crisis and Mortality Communications and the Information Environment

Prior to Hurricane María (June 1-September 19, 2017)

Crisis and Emergency Risk Communication Plans and Inter-agency Coordination

Guidelines from CERC, WHO and FEMA specify the establishment of Emergency Communication Plans that: emphasize a continuous strategic planning process focused on both preparedness and response; call for collaboration between agencies and local stakeholders and communities; detail personnel resources, annual training and surge capacity; include pre-positioned communication resources/materials; identify mechanisms for messaging monitoring and adjustment and are responsive to evolving contexts.

- According to interviews with DPS and the DoH personnel, after the establishment of the DPS, which integrated key emergency and first responder agencies (Emergency Management Bureau (EMB), Police, 911, Firefighter Corps, Medical Emergency Corps, Special Investigations Bureau) and the BFS, emergency plans for agencies under the DPS umbrella were not updated and coordinated between agencies, including the communication plans. This led to inoperable and disconnected emergency plans and a lack of clarity about crisis and emergency risk communication protocol when Hurricane María struck.

- Interview participants from the DPS, various offices within the DoH and EMB indicated there were also no written, updated agency crisis and emergency risk communication plans in place that specified coordination after DPS's establishment in April 2017.

- Interviews with leadership at the Governor Office's Central Communications Office indicated that no written crisis and emergency communication plans were in place at the time of the hurricane.
- Leadership from the EMB, the agency responsible for reviewing and approving agency and municipal emergency plans, indicated that their existing emergency plans were appropriate for Category 1 hurricanes and did not include scenarios such as multiple cascading failures in critical infrastructure and key resource (CI/KR) sectors, as specified in the Department of Homeland Security's National Planning Scenario (NPS) #10, for "Category 3 of Higher Hurricane."
- According to interviews with personnel in the DoH Office of Emergency Preparedness and Response, as well as our review of the annexes from the emergency plan, the plan had not been updated to reflect DPS's establishment, but did include annexes for Risk Communication in Emergencies and Mass Fatality Management. Interview respondents did not mention the existence of an updated, written plan for mortality surveillance in emergencies, which would specify agency responsibilities, coordination and clearance protocols for public reporting.
- Key leader interview participants perceived inadequate preparation by the Government of Puerto Rico and the federal government, evidenced by the unsuccessful communication between municipalities and the COE, a disabled hospital system, deficiencies in communication among first responders, handling of deceased and lack of coordination of health personnel for refuges. Furthermore, key leaders expressed that Hurricane María revealed Puerto Rico's social and health inequities.

Communication Personnel Staffing Structure, Training, Processes and Responsibilities

- Leadership within the Governor's Central Communications Office indicated that their office oversees and coordinates agency Press Directors, but does not implement, oversee or coordinate activities outside of press-related functions, such as crisis and risk communication or health/safety promotion. This office indicated responsibility for providing general training for communication personnel, and identified agency leadership as responsible for providing agency-specific training.
- Based on interviews with government agency personnel, communications staff allocation was imbalanced, with more personnel dedicated to press relations and inadequate personnel dedicated to other important areas of communications, including crisis and emergency risk communication. This is evident in the staffing structure across agencies–it is common for there to be one or few communications personnel per agency, with staff having expertise and primary functions in press relations. According to interviews, there were no personnel within Puerto Rico Government agencies who were identified as responsible for training communication personnel across agencies in crisis and emergency risk communication.

At the time of the hurricane, numerous agency communication personnel had not been trained in crisis and emergency risk communication, nor were they trained regarding their role in a disaster.

- Interview participants from the DPS and various offices within the DoH described hurricane-related mass media risk communication campaigns as primarily implemented annually by contracted public relations/advertising agencies, with collaboration from government agencies. These contracted personnel were not mobilized as surge capacity in emergencies.
- Based on responses from government personnel in the Central Communications Office and key leaders in municipalities, it is evidence that the personnel structure between central and municipal governments to facilitate emergency communication was inefficient and ineffective for catastrophic disasters. According to Central Communications Office interview respondents, the Municipal Affairs Office in the Governor's Office interacts with municipalities, but not for emergency communication functions.

Risk Communication Messaging and Local Preparedness Communication Efforts

- Key leader interview respondents reported that in the months prior to the hurricane, they were exposed to risk messages disseminated via television, radio and social media. Most respondents recalled risk messages targeting vulnerable groups or related to hurricane preparation about food, water, shelter, medication and evacuation. Respondents recalled less health-related prevention or risk messages, such as potential consequences of failures in critical infrastructure and key resource sectors that one might anticipate from a Category 4 or 5 hurricane, subsequent health implications and how to navigate these challenges.
- Key leader interview participants described preparations undertaken in their respective communities, including activities such as: 1) designation of neighborhood leaders to facilitate communication, provide vigilance and attend to resident needs; 2) local census of bed-ridden individuals, older adults and other sensitive populations; 3) use of mobile applications, such as WhatsApp, to facilitate communication among local stakeholders; 4) local inventories of health professionals and first responders who could be called upon during response efforts; 5) implementation of risk messages, such as evacuation and relocation of vulnerable individuals or households; 6) coordination of local emergency response teams and 7) training of community leaders to meet the needs of vulnerable groups, such as those with diabetes.

- Key leaders reported that, despite the mass media campaign and local preparedness efforts, communities were not adequately prepared for the direct and indirect impacts of a Category 4 hurricane: segments of the public did not take the warnings as seriously as they should have; segments of the public had prepared, but not with adequate supplies or arrangements for vulnerable populations for an extended time period; and some respondents thought that there was no way to plan for some of the unforeseen circumstances from Hurricane María. The lack of recent history with a major event may have also influenced how the public understood the risk.

  - Vulnerable populations identified by key leader interview respondents included: low-income individuals who could not prepare adequately due to limited financial resources; older adults; individuals with chronic medical conditions; patients requiring ongoing and specialized treatment; and patients with required prescription medications, including controlled substances.

According CERC and WHO framework guidelines, government administrations build public confidence in disaster preparedness and response capabilities by having in place: appropriate communication personnel and leadership; coordinated procedures for transparent public information sharing, stakeholder engagement, and rumor control; appropriate channels for information dissemination; and trained, agile spokespeople who strategically involve experts when necessary, utilize tested communication strategies, provide consistent, verified information free of suppositions and deliver information in a way that instills trust and transparency.

Communication Personnel, Training and Inter-agency Coordination

- According to Puerto Rico Government communications personnel interviews, there was a high level of interaction among inter-agency communication personnel located in the COE, but an overall lack of coordination of messaging, public information clearance and sharing of information for situational awareness between the COE and municipalities, primarily due to the loss of telecommunications and inadequate contingency plans. This resulted in the dissemination of information via media channels that was inconsistent with information from the COE.

- Communication personnel interview participants described deficiencies in coordination between Government of Puerto Rico communication personnel and CDC, Department of Health and Human Services (DHHS) and FEMA counterparts located at the COE.

- Government agency communications personnel also cited challenges in responding to an elevated number of media inquiries due to insufficient staffing.
- Government agency communications personnel interviews indicated that surge capacity was not adequately mobilized at the time of the hurricane. COE communication personnel worked 12-hour shifts (or longer) every day for weeks to months post-hurricane.

Risk Communication, Channels, and Local Communication Strategies

- According to interviews with government agency personnel, the collapse of telecommunications and power infrastructure challenged situational awareness, impaired informed decision-making and delayed information dissemination to the media and the public.
- Government communication personnel indicated that they relied on mass media for information dissemination; however, according to key leader interviews, many Puerto Ricans experienced extended power and telecommunications outages. Social media was not highlighted by communication personnel as a major channel of information exchange with the people of Puerto Rico or stakeholder engagement, except for dissemination of press conferences and information via Facebook. Responses from interviews with government communication personnel indicated they did not engage in strategic rumor monitoring and control activities via social media or other channels post-hurricane.
- Key leader interview participants identified three mechanisms of post-hurricane information exchange: text messaging, police radios and direct interpersonal communication, with the latter being the most widely used. However, interviews indicated interpersonal communication was not strategically utilized by government personnel for mortality and disease surveillance or for coordinated post-hurricane health and safety risk and prevention messaging. Key leaders cited numerous "missed opportunities" by DoH personnel to efficiently and resourcefully use interpersonal communications post-hurricane. Key leader interview respondents described specific situations when they attempted to relay mortality or disease surveillance information via interpersonal communication, but they perceived inadequate follow-up from DoH leadership.
- Key leaders cited radio as a relatively reliable and credible channel of post-hurricane communication; however, this channel was reported as utilized only to a very limited extent for disseminating health-related prevention messages and information. Respondents highlighted perceived inadequacies of health-risk communication messaging, even after telecommunications services were restored.

- Key leaders identified trusted information sources, including local representatives, community leaders and individuals who align with the same political party; however, there was limited engagement by government personnel of local representatives or leaders for coordinated risk communication efforts in local communities.

Mortality Reporting

- Generating an accurate death count in an emergency and communicating this information to the public is complex and needs to be well established. Damaged infrastructure and power and telecommunication outages presented major challenges to mortality surveillance, creating difficult circumstances for reporting this information to the public in a timely manner.

- Government agency interview participants did not know of a formal, written protocol in place for the coordination of mortality reporting between the DPS and the DoH.

Agency leadership interview respondents from both agencies agreed on reporting deaths as hurricane-related if classified as such on the death certificates. According to interviews with communication personnel, appropriate technical experts were not involved in the timing, clearance or delegation of responsibilities for public reporting of mortality. Personnel from the DoH Office of Public Health Preparedness and Response indicated that no unified, interagency command was designated to coordinate, provide clearance and report mortality in emergencies, a practice that existed previously. As of April 2018, leadership of the DPS and the DoH continued to disagree about which agency would be responsible for mortality reporting in future emergencies.

- A review of information from press releases, press conferences, media coverage and social media commentary indicates that the Government of Puerto Rico apparently did not provide the public with an overview of the complex death certification process, which would have laid the foundation for interpreting subsequent mortality reporting and helped to explain factors contributing to delays. This, combined with delays in mortality reporting due to the storm's aftermath, resulted in major information gaps, which facilitated the emergence of rumors in an attempt to have the public's questions answered.

Numerous attempts were undertaken by outside groups to fill these information gaps and employ alternative mechanisms to identify hurricane-related deaths, resulting in numerous conflicting mortality reports. The perceived lack of consistency in mortality reporting was reflected by key leader interview respondents, who indicated that the multiple reports added to confusion and perceived non-transparency.

- Post-hurricane media coverage included interviews with physicians and funeral home directors who called into question clarity and consistency of the death certification process. According to key leader respondents, the public did not sufficiently understand the importance of designating deaths as hurricane-related, but once they learned of potential documentation discrepancies and implications, official mortality report credibility suffered. Several key leader respondents perceived the official death toll to be an undercount given their direct experiences with mortality in their individual municipalities. The perception that the death count was higher led some key leaders to view government leadership as disconnected from the realities of Puerto Rican communities, that there was not transparency in reporting, that information was intentionally withheld to evade blame and that there were not adequate systems in place to track death count.

- According to a review of media, official sources were cited as reporting the authorization of hundreds of cremations from September 20 to October 18 for cadavers with certifications of a natural death; media reported this as being an elevated number of cremations from the year prior to the hurricane. However, explanations of cremation trends by a government subject-matter expert were not available in media coverage, leaving lingering suspicions of non-transparency in reporting deaths as hurricane-related and increasing risk of rumor generation.

- A review of media coverage and social media commentary noted that the abrupt increase in reported deaths from 16 to 34 on October 4th was perceived by the public as an effort to manipulate the death count for political interests, contributing to the controversy. A review of media coverage, press releases and press conferences revealed that no explanation was given to fill this void of information, such as a description of the "Burkle Effect," a phenomenon seen in post-disaster contexts, where a virtual collapse of mortality surveillance immediately after the event is followed by a spike in mortality reporting as recovery progresses.

- Media coverage and social media commentary showed that additional controversy resulted from the publicized potential deficiencies in accounting for indirect deaths in media coverage. After a series of questions from the media, the Secretary of Public Safety said in a press appearance on November 8th that the government would announce only the deaths that doctors certified. Potentially adding to the controversy, media coverage continued to report anecdotes of indirect deaths due to persistent power outages and injustices in receiving federal benefits due to the lack of documentation of indirect deaths. The extended post-hurricane recovery period led some key leader interview respondents to perceive that indirect deaths occurring up to months post-hurricane were not being captured in the official death count.

- Key leader interview participants believe it is important to know more about the death count and cause of death for future disaster preparedness planning and response efforts. Overall, they supported the reassessment of the death count from Hurricane María the Governor ordered, especially if the findings could be informative for future disaster preparedness planning.

Spokespersons Roles Following Hurricane María

- The lack of coordinated crisis communication and media training across Puerto Rico Government agencies and their spokespersons were evident, given spokesperson performance during press conferences or media interviews and negative perceptions and characterization of how they conveyed messages or of their capabilities, as reported in media coverage and social media commentary.
- Contradictory information and the release of unconfirmed information to the media, including death reports, demonstrated a lack of clearance protocol (or adherence to the protocol), personnel training and coordination of messages by government officials. These contradictions and apparent lack of coordination may have contributed to decreased credibility of the government.
- The Governor of Puerto Rico served as the main spokesperson both pre- and post-hurricane. A review of press conferences indicated he seemed prepared with relevant information and talking points, which aligned with press releases from his office. An examination of the Governor's interactions with the press, using criteria from the WHO and CDC guidelines showed he listened to questions and responded with facts without using technical language; he managed uncertainty by saying what was known and what had been done, while also identifying what was still in the process of being reviewed or updated; and he acknowledged uncertainty in the death count early and indicated a willingness to provide information when it became available. However, the Governor deferred to the Secretary of Public Safety on numerous occasions instead of calling upon an expert to provide information about mortality surveillance.

- The Secretary of Public Safety was a frequent spokesperson post-hurricane. In accordance with WHO and CDC spokesperson criteria, during his interactions with the media, the Secretary delivered clear, concise information; conveyed authority; acknowledged uncertainty in the mortality count; and also indicated a willingness to provide more information when it was available. However, he did not provide details about the death certification process, identify specific barriers to this process, or explain reasons for delays or lack of information. The Secretary did not identify a subject-matter expert early in the post-hurricane period to provide these details, which may have decreased credibility and increased the perceived lack of transparency evident in media reports and social media commentary. It was not until a November 8th press conference when subject-matter experts were available to respond to questions about mortality; inclusion of such experts in media presentations earlier in the recovery period would have been ideal. Furthermore, a review of media coverage and press conferences in the post-hurricane period indicated that the Secretary provided contradictory information when he stated that the government would not be influenced by assumptions, but then offered estimations about average increases in daily deaths without detailing the source or calculation of these statistics or the rationale for using them. This likely added to doubts about the government's transparency.

- Despite the active, extensive dialogue on social media about the mortality issue, no government agency communication personnel we interviewed described any efforts to engage with social media audiences as part of an overarching social media strategy, potentially a missed opportunity and a flaw in the overall communication strategy.

RECOMMENDATIONS

RECOMMENDATIONS ON CRISIS AND HEALTH COMMUNICATION IN NATURAL DISASTERS

I. Strategic Objective

To use credible, transparent and effective crisis and risk communication during natural disasters as a mechanism for informing populations, protecting lives and instilling public trust. The following guiding principles are recommended:

- Preparedness, with planning as fundamental for effective crisis and emergency risk communication
- Credibility, as a critical factor for facilitating partnerships and protecting public health
- Transparency, as a mechanism for strengthening and informing decision-making
- Compassion, with acknowledgment and validation of individual and societal emotions and concerns

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II. Programmatic Recommendations for Natural Disaster Crisis and Mortality Communications

A. Develop a Crisis and Public Health Communication Policy and Organizational Development Agenda

Create an Integrated Puerto Rico Crisis and Emergency Risk Communication Plan and Planning Process

- Establish a continuous planning process under the leadership of EMB and Central Communications Office that integrates all responsible agencies and municipalities for the development of a Puerto Rico Crisis and Emergency Risk Communication Plan.
- Define roles, levels of engagement and specific tasks for municipalities and agencies.
- Establish Crisis and Emergency Risk Communication Plans and planning processes for government agencies and municipalities.

- Engage key stakeholders and local communities in the development of Crisis and Emergency Communication Plans at the municipal, agency, and Puerto Rico Government levels.
- Specify the following in the plans:
  - The roles and responsibilities for communication personnel
  - Appropriate procedures, protocols and actions necessary in different crisis phases according to CERC guidelines (pre-crisis, initial, maintenance, resolution and evaluation)
  - Coordination with Puerto Rico and federal government agencies, institutions and key stakeholders
  - Key target audiences (including vulnerable populations), messages and dissemination channels before and after emergencies with specified contingencies
  - Messages about mortality and other health impacts to be conveyed to various target audiences, as well as the modes and channels for dissemination of this information
  - Creation of tools and materials that are appropriate for communication about disaster-related mortality
  - A team responsible for updating Puerto Rico, agency and municipal plans at least annually and following disasters

Define clear leadership and alignment for effective, transparent and credible public health communications in disasters.

- Identify a cadre of official spokespersons for disasters, including subject matter experts.
- Create a clear protocol for public release of messages and information-sharing between agencies.

Coordinate and Build Capacity for Crisis and Emergency Risk Communication

- Create an interagency and multilevel coordinating architecture to support key public health communication functions
  a. Coordinate Puerto Rico Crisis and Risk Communication Plan with Agency and Municipal Plans.

b. Establish an inter-agency committee to coordinate crisis and emergency risk communication preparedness and response across agencies, including the coordination and oversight of mortality surveillance clearance and reporting to the public in disasters, to include communications and technical experts.

c. Establish a formalized network of municipal communication liaisons to facilitate the timely exchange of information with the central government pre- and post-disaster.

Ensure personnel capacity for effective crisis and emergency risk communication

- Staffing structures in government agencies must be reassessed. Staffing structure in disasters needs to be established in crisis communication plans. Consider how staffing level needs evolve as a disaster unfolds, across agencies, and across public health communications functions.
- Personnel must be hired within government agencies responsible for public health and safety with expertise in emergency communication planning and management, crisis and risk communication, and mortality communications. Consider adding personnel with these areas of expertise for the Central Communications Office, the DPS and EMB, in particular, given its role in overseeing municipal and agency emergency plans.
- Given the growing importance of social media, especially in disasters, dedicate staffing for disseminating information to social media as well as closely monitoring responses on social media; this is essential to an integrated emergency risk communication effort and information exchange during all phases of a disaster.
- Consider finding a fiscal balance between contracting of public relations/advertising agencies for public information campaigns and bolstering a cadre of permanent communication personnel within government agencies, the latter of which can play a direct role in the emergency response and recovery process.

Broad community engagement in disaster communication preparedness and response activities

- Ensure broad community involvement as a critical approach to developing crisis and emergency risk communication plans and messages.
- Strengthen community engagement during the crisis and emergency risk communication preparedness planning process by using participatory approaches and establishing strategies that will capitalize on this engagement for improved communication during the response and recovery period, such as utilizing interpersonal networks to disseminate information as a complement to mass media channels.

III. Recommendations to Build Crisis and Mortality Communications Preparedness Capacity for Natural Disasters

- Update Puerto Rico, agency, and municipal Crisis and Emergency Risk Communication Plans annually and following disasters.
- Provide annual crisis and emergency risk communication training for communications personnel, to include monitoring and addressing rumors and the effective use of social media in disasters.
- Implement media training for disasters with designated spokespersons.
- Conduct annual disaster preparedness exercises and simulations for communications, including key stakeholders and local communities.
- Develop a dashboard that characterizes current crisis and mortality communication capacity in disasters and tracks advancement over time for management and accountability.
- Conduct a KAP (knowledge, attitude and perception) population study to identify communication strategies, messages, key audiences, vulnerable groups, and communication channels in disasters.
- Conduct research for the development of best practice guidelines for mortality communication to the public in disasters, building on lessons learned from Hurricane María.
- Disseminate broadly promising practices and lessons learned for community-based disaster preparedness and response.
- Develop an ongoing process for crisis and emergency risk communication capacity building through the engagement of external experts, advisors, academics and practitioners with expertise in this area.

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ANNEX 1

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GW Team

Dr. Elizabeth Andrade, Dr.P.H., M.P.H.
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Elizabeth Andrade is Assistant Professor in the Department of Prevention and Community Health and the Administrative Core Director of the Avance Center for the Advancement of Immigrant/Refugee Health at GW's Milken Institute School of Public Health. Dr. Andrade is a behavioral scientist with expertise in planning, implementing, and evaluating public health interventions, health communications, and health disparities research using community-based participatory methods. She has worked extensively with immigrant Latino populations in the Washington DC Metropolitan Area and with communities in Latin America.

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Nicole Barrett is a Senior Research Associate at GW's Milken Institute School of Public Health, Department of Prevention and Community Health. She has expertise in qualitative research, community-based participatory research, and social marketing and health communication. She supports various research projects with instrument development; IRB submissions and approvals; manuscript, report and conference presentation development; data collection and analysis; and grant proposal submissions.

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Uriyoan Colón-Ramos is a Professor in GW's Department of Global Health and the Department of Exercise and Nutrition Science. She is a public health nutrition investigator. She has published about mortality and diet-related chronic disease morbidity in Puerto Rico. Her work has contributed to the knowledge of existing dietary disparities among Hispanic subgroups, the process of translation of science into nutrition policy in Latin America and the social and environmental determinants of dietary behaviors among vulnerable populations in the US, Latin America and the Caribbean.

Dr. Mark Edberg, Ph.D., M.A.
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Mark Edberg is an Associate Professor in the GW's Department of Prevention and Community Health, with appointments in the Department of Anthropology and Elliott School of International Affairs. Dr. Edberg is currently principal investigator and director of the Avance Center for the Advancement of Immigrant/Refugee Health, an exploratory research center with funding from the National Institute on Minority Health and Health Disparities and the CDC. He is also founder and director of the Center on Social Well-Being and Development.

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Alejandra Garcia-Meza is a Research Associate at GW's Milken Institute School of Public Health, Global Health Department. She has experience in policy analysis, stakeholder mapping, program impact evaluation, qualitative and quantitative analysis, clinical research and grant management. She is currently collaborating with the Yale School of Public Health and the Pan American Health Organization on developing a course for health ministries in Latin-America to evaluate and develop continuous quality control systems for nutrition programs and interventions.

Dr. Ann Goldman, Ph.D., M.P.H, M.A.
Epidemiologist, Economist, Project Coordinator

Ann Goldman, originally from Puerto Rico, has worked on researching the costs of prevention programs and other economic topics within different institutional settings for the last 15 years. She has been involved in designing and implementing protocols for cost analysis and cost effectiveness studies on population health intervention initiatives. The projects she has worked on have sought to enhance the abilities of members of vulnerable groups, in the developing world as well as in the US, to achieve improved health and enjoy a better quality of life.

Dr. Lynn Goldman, M.D., M.S., M.P.H.
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Environmental Health Specialist, Project Researcher

Lynn Goldman's responsibilities are informed by her broad and deep public policy and academic experience. Dr. Goldman was Assistant Administrator for Toxic Substances in the Environmental Protection Agency under President Bill Clinton. Under her watch, the EPA overhauled the nation's pesticide laws, expanded right-to-know requirements for toxin release, among other achievements. She participated in several discussions on Hurricane Katrina's environmental public health impact. She is a member of the National Academy of Medicine and serves on the National Academy of Medicine Council, the Governing Board of the National Academy of Sciences and as a member of the Advisory Committee to the CDC Director and a member of the Food and Drug Administration Science Board.

Dr. Amira Roess, Ph.D., M.P.H.
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Amira Roess is an assistant professor at GW's Milken Institute School of Public Health, Department of Global Health. She is an epidemiologist with expertise in infectious diseases and interventions to reduce the transmission and impact of infectious diseases, especially emerging and zoonotic diseases globally. Dr. Roess has expertise in mortality analysis and addressing US health disparities.

Dr. John Sandberg, Ph.D., M.A.
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John Sandberg is an Associate Professor in GW's Department of Global Health, trained as a social demographer. He has published several works on US children's time use, including analyses of how they spend time and changes occurring in time use in the last 20 years, as well as determinants and patterns of children's time use with fathers in two-parent families. His current research explores the relationship of children's time use to parental child-socialization values and gender-role attitudes.

Dr. Carlos Santos-Burgoa, M.D., Ph.D., M.P.H.
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Carlos Santos-Burgoa is a Professor in GW's Department of Global Health, where he also serves as the Program Director for the Global Health Policy MPH program. Dr. Santos-Burgoa is raising awareness of the importance for equity and development of the public health functions within the health systems and seeking to advance their performance. He was Dean of the School of Public Health of Mexico at the National Institute of Public Health, Director General of the Health Environment and Work Institute–a private consulting and research firm, Director General at Mexico´s Ministry of Health and Senior Advisor and Acting Department Director at the Pan American Health Organization. As Director General for the Ministry of Health in Mexico, Dr. Santos-Burgoa was in charge of disaster management in the 2007 Tabasco floods and the non-pharmacological response to the 2009 Pandemic Influenza A(H1N1) in Mexico. He was also responsible for chemicals emergency management in Mexico and updated the Radiologic Emergency Program for nuclear facilities.

Dr. Scott Zeger, Ph.D., M.S.
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Biostatistician, Project Researcher and Expert Panel Member

Scott Zeger is a Professor of Biostatistics at the Johns Hopkins Bloomberg School of Public Health. He conducts statistical research on regression analysis for correlated responses in surveys, time series and longitudinal or genetics studies. Professor Zeger has been elected Member of the National Academy of Sciences' Institute of Medicine, Fellow of the American Association for the Advancement of Science and of the American Statistical Association. He was originally invited as an external panel expert. He is incorporated in this list as he got heavily involved in the project's analysis of excess mortality component.

UPR GSPH Team

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Noel Estrada is in Graduate School of Public Health, Department of Epidemiology and Biostatistics. He received a bachelor's degree in Cellular & Molecular Biology from the University of Puerto Rico, Rio Piedras Campus. He is currently studying the differences in survival for hepatocellular carcinoma and underlying diseases. His research interests are cancer, chronic diseases and emergency management. He also served as research assistant in the Eastern Caribbean Health Outcomes Research Network (ECHORN) collaborative project.

Dr. Cruz María Nazario, Ph.D.
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Cruz María Nazario is a professor in the Biostatistics and Epidemiology Department, Graduate School of Public Health, University of Puerto Rico. She has mentored over 130 master's and doctoral students. Her career combines long experience in fieldwork and epidemiologic study design and analysis, with her academic work and the defense of the right to health for poor communities in Puerto Rico. Dr. Nazario is a member of the Robert Wood Johnson Foundation National Advisory Committee, Clinical Scholars Program.

Dr. Cynthia Pérez, Ph.D.
Epidemiologist, Project Researcher

Cynthia Pérez is a Professor of Epidemiology in the Graduate School of Public Health at the University of Puerto Rico. She has directed mentoring and training of public health students, medical students, residents, fellows and faculty in the fields of epidemiology and biostatistics for the past 20 years. Her research has spanned public health issues in Puerto Rico, where she has designed, implemented and administered population-based studies targeting various geographic areas in the island. She has also devoted some of her time to coauthor various books including *Biostatistics in Public Health Using Stata and Applications of Regression Models in Public Health.*

Dr. Erick Suarez Pérez, Ph.D., M.A.
Biostatistician, Project Researcher

Erick. Suarez is a biostatistician in the Graduate School of Public Health, University of Puerto Rico . He has been involved in various research projects, where he developed the experience to apply statistical analysis and rigorous methodologies to public health problems in population-based studies and secondary data analysis. He has coauthored two books related to public health: Biostatistics and Public Health (CRC/Press, 2016) and Applications of Regression Models in Epidemiology. In addition, he has worked with microarrays data analysis to assess the gene expression and DNA repair capacity among breast cancer patients.

Additional GW Team Members

Ljubica Latinovic, M.D., M.H.A.
Communications Expert, Consultant

Ljubica Latinovic is a specialist in risk communication. She currently serves as a risk communications advisor for the Pan American Health Organization, providing support to countries when necessary. She has long-term experience at the Health Promotion Department of the Ministry of Health of Mexico where she worked in risk communication and managed social marketing. She has also worked in crisis risk communication for the Ministry of Health in Mexico during the 2009 Influenza Pandemic. She has coordinated and designed strategies for risk communication in emergencies and disasters with Collaborating Centers for International Health Regulations.

Ivonne Rivera, M.P.H.
Expert in Qualitative Analysis, Consultant

Ivonne Rivera is an expert with over 15 years of experience in qualitative research. She leads a consulting practice that provides services to organizations in designing and conducting qualitative research studies, as well as supporting research activities with transcription and translation. Her clients have included government agencies, research companies and advertising agencies. She has expertise working with various communities nationwide, allowing her to take a culturally and linguistically appropriate approach with research participants. She also has 13 years of experience working in clinical research.

ANNEX 2

External Panel of Experts

Samuel Clark, Ph.D., M.A.
Demographer

Samuel Clark is a demographer who works on African demography and epidemiology and developing new methods for population sciences. His work includes improving the 'verbal autopsy' method used to quantify the burden of disease for populations without full-coverage vital statistics systems. He also works in developing new population indicator measurement strategies, and in a variety of projects investigating levels and trends in fertility and mortality, mostly in Africa, and sometimes building models of age schedules of fertility and mortality that can be used widely as inputs to other analyses. His work involves collaborations with the CDC, WHO, UNICEF, among others. He was invited to join the Puerto Rico expert panel due to his expertise in verbal autopsies and his wealth of experience as a demographer, which helped inform the methods for estimating excess mortality from Hurricane María.

Debarati Guha Sapir, Ph.D.
Epidemiologist

Debarati Sapir is the Director of the Center for Research on the Epidemiology of Disasters and a Professor at University of Louvain School of Public Health, in Brussels, Belgium. She holds an Adjunct Professorship at Tulane University Medical Centre (New Orleans) for Health and Humanitarian Aid. The GW SPH team invited Dr. Sapir to join the expert panel due to her expertise in research methods for disaster epidemiology. Since 1984, she has been involved in field research and training in emergency and humanitarian aid issues, working closely with WHO, UNHCR, UNDP and European Commission in various regions of the world. Her experiences provided seasoned input in the study design and methods and critical and constructive feedback on the project results.

Bernardo Hernández Prado, DSc., M.S.
Epidemiologist, Mortality Estimation Expert

Bernardo Hernández Prado is an Associate Professor at the Institute for Health Metrics and Evaluation (IHME) at the University of Washington. He works with IHME's Integrated Surveillance Systems research team in evaluating the Salud Mesoamérica 2015 project. Dr. Hernández has collaborated with IHME on the Population Health Metrics Research Consortium project for validating verbal autopsy and chronic disease diagnosis questionnaires. Dr. Hernández's work on verbal autopsies, a key component of Phase II of this project helped inform the methods. His research has focused on maternal health and mortality, social and health program evaluation and the effect of physical activity and improved nutrition on the health of children and mothers. His overall work experience with research and data analysis also proved to be incredibly useful for the mortality estimation component.

Matthew Seeger, Ph.D.
Communications Expert

Matthew Seeger is currently Dean of the College of Fine, Performing and Communication Arts at Wayne State University. His research concerns crisis and risk communication, health promotion and communication, crisis response and agency coordination, the role of media (including new media), crisis and communication ethics, failure of complex systems and post-crisis renewal. He has worked with the CDC and the National Center for Food Protection and Defense. He is also a member of the WHO Guidelines Development Group for Emergency Risk Communication. He is currently involved in a multi-year, interdisciplinary project focusing on contamination of the Flint, Michigan water system. His expertise provided invaluable guidance on the methods and findings for the project's communications component.

Dr. Scott Zeger, Ph.D., M.S.
(Johns Hopkins University, Bloomberg School of Public Health)
Biostatistician

Scott Zeger is a Professor of Biostatistics at the Johns Hopkins Bloomberg School of Public Health. He conducts statistical research on regression analysis for correlated responses in surveys, time series, longitudinal or genetics studies. Dr. Zeger has been elected a Member of the National Academy of Sciences' Institute of Medicine, Fellow of the American Association for the Advancement of Science and of the American Statistical Association. He was originally invited as an external panel expert and is listed here as he got heavily involved in the analysis of excess mortality component of the project.

Internal Technical Experts

Daniel Hoffman, Ph.D., M.P.H.,
Epidemiologist

Daniel Hoffman's career has blended research, public service and a commitment to training a new generation of public health professionals. Dr. Hoffman has pursued interests in environmental hazards, cancer epidemiology and leadership capacity-building. He was appointed the School's first Associate Dean for Public Health. He currently directs the School's Eastern and Central European Health Leadership Program, funded by USAID. Dr. Hoffman was asked to join the internal expert panel due to his experience in building capacities for National Disaster Medical System Hospitals staff and work in disaster epidemiology.

Pietro Marghella, DHSc, MSc, MA, CEM, FACCP
Complex humanitarian emergencies expert

Piertro Marghella is an expert on medical and public health preparedness and response for large-scale disasters and complex emergencies. He served for 20 years as a Medical Plans, Operations, and Intelligence Officer in the United States Navy, retiring as the Director of Medical Contingency Operations for the Office of the Secretary of Defense. He is a Fellow in the American College of Contingency Planners (ACCP), which he co-founded and served as first President. Dr. Marghella was appointed as a Special Advisor to the Secretary of Health of Puerto Rico after Hurricane María. His knowledge of the disaster and experience in complex humanitarian emergencies made him an invaluable expert to advise on this project.

Sam Simmens, Ph.D., M.A
Biostatistician

Sam Simmens emphasizes the social and behavioral components of public health-related statistical methods. As a researcher, he collaborates with colleagues in all of the health-related fields, applying his skills to research focused on HIV, cancer, obesity, mental health, maternal and infant development, chemical and stress-related environmental exposures and numerous other health issues. He is the Director of GW's Biostatistics and Epidemiology Consulting Service (BECS)for all faculty.

Ronald Waldman, M.D., M.P.H.
Complex humanitarian emergencies expert

Ronald Waldman began his career in WHO's Smallpox Eradication Program. He joined CDC's Epidemic Intelligence Service in 1979 and was assigned to the Refugee Health Unit in Somalia, where he worked intermittently through 1985. He then became Director of the Technical Support Division of CDC's International Health Program Office. He has worked in numerous emergency settings in policy and coordination roles, including the Iraq War of 1991, the aftermath of the Rwanda genocide, and the Balkan Wars. He was the USG Coordinator of the health sector relief effort following the Haiti Earthquake and, later that year, a senior advisor to the UN Office for the Coordination of Humanitarian Affairs in Pakistan. He is currently Professor of Global Health at MISPH and the President of Doctors of the World – USA.

ANNEX 3

AIM: Attribution of direct and indirect deaths: An in-depth analysis of cause-specific mortality from Hurricane María

The first phase of this study aimed to identify the total excess mortality in the six months following Hurricane María, which made landfall in Puerto Rico on September 20, 2017. The second phase of this project seeks to identify which deaths were directly and indirectly attributed to the hurricane.

A. Study Justification and Aim

- Identify vulnerable populations most at risk for mortality following the hurricane, either based on underlying health conditions, residential location and/or socioeconomic status. This information is essential to inform preparedness and response protocols to target the most vulnerable populations and those facing unprecedented morbidity from chronic conditions amid a failing health system. The results of this proposed analysis are critical for reducing the human toll of future disasters.
- Use a standardized, rigorous, scientific process to investigate the circumstances in which deaths occurred immediately after, and in the six months following, the hurricane. Those circumstances must be taken into consideration when systematically assigning mortality attribution to the hurricane. In addition to informing preparedness and response plan, the methodology proposed will advance the science of public health in ascertaining cause-specific deaths in future natural disasters.

B. Methods

- The protocol developed was informed by a series of systematic literature reviews. We propose to build upon new CDC guidelines by developing methods to collect and integrate contextual information (e.g., location, underlying health condition, socioeconomic status, events leading up to the death) with a systematic algorithm to identify conditions that could have contributed directly or indirectly to the deaths observed in the event's aftermath. These conditions will be obtained from multiple sources of data.

B.1. Systematic literature reviews

- Develop and test a methodology to ascertain direct, indirect and possibly attributable deaths to natural disasters, building upon the work of other researchers in response to Hurricanes Ike and Sandy in the US and the Fukushima triple disaster in Japan.
- Address these critical gaps found in literature reviews:
  - Lack of consensus on a definition and time frame for attributing indirect mortality following a disaster
  - Lack of consensus on guidelines for a process that integrates verbal and social autopsies with official mortality data to ascertain indirect causes
- Work with the external advisory panel to develop and implement methods

B.2. Identification and acquisition of multiple sources of data to describe the circumstances of the deaths

- Use datasets from the Bureau of Forensic Sciences, 911 emergency calls obtained from the Bureau of Police and FEMA data.
- A future step will explore the feasibility of including deaths of Puerto Ricans who were living there until after the hurricane but died outside of Puerto Rico in key states (i.e., Florida, New York) to develop a comprehensive dataset.

B.3. Development of procedure to attribute causes of death

- Develop an algorithm to identify the likely conditions leading to direct and indirect mortality cases from the hurricane. The algorithm is designed to describe:
  - *Direct Causes.* This would also include a finite timeframe for such forces that would act directly on the individual (to be discussed and defined).
  - *Other Causes (Indirect, Probable)*: We would divide these into the four major causes of death commonly used in forensics pathology: accidental/injuries, suicide, homicide and natural deaths (we identified the top nine causes of death in Puerto Rico and will complement this information with the prevalence report of ICD-10 codes during the timeframe considered for this study).
  - Information about circumstances, context, time-frame and death codes in the algorithm will be transformed into an algorithm that can identify the deaths that are (a) attributable to hurricanes; (b) possibly attributable to hurricanes but lack key confirmatory data; and (c) not attributable to hurricanes. We will pilot test the performance of the algorithm with all of the deaths currently directly attributed to the hurricane.
  - We will randomly identify a sample among 'other' deaths to characterize their mortality circumstances, based on criteria of interest and vulnerability.

B.4. Development of methods to investigate deaths that are 'possibly attributable to hurricanes'.

- Work with our global expert panel and local/technical expert panel to decide on a sampling criterion for further investigation of possibly attributable to hurricanes but lack key confirmatory data' cases.
- Split the 'possibly attributable to hurricanes but lack key confirmatory data' sample into one of two categories.
  - Cases who received care in their final days at a medical facility
  - Cases where deaths occurred outside of a hospital or within a medical facility with limited diagnostic capability.
- Two next steps will be taken:
  - Conduct medical record abstraction to identify the context-specific conditions in the first group, and/or
  - Perform a verbal and social autopsy for those in either group following a predefined protocol.

C. Ethical considerations, protection of human subjects and confidentiality

The GW SPH and UPR GSPH IRBs will review all data collection, analysis and storage procedures and protocols to ensure they comply with the guidelines and regulations required for protection of human subjects. All procedures will follow ethical principles to show respect for persons, beneficence and justice, via informed consent for primary data collection, confidentiality for all data and minimization of risks for all procedures.

D. Expected Final Product

The findings from this study will inform the development of a set of recommendations to be considered by the Bureau of Forensic Sciences for reclassification of causes of deaths in relation to their attribution to the hurricane. We will also provide a procedure to analyze and define the context and conditions that lead to a death being attributed to a hurricane which can be used as an input to improve current guidance and practice. We will develop a communication brief to explain the procedure to policy-makers and the public.

https://prstudy.publichealth.gwu.edu/

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