Impact of Hurricanes Irma and Maria on Asthma, Hypertension, and Depression in a Sample of the Puerto Rico Population

Marijulie Martínez-Lozano CPH, DrPH[1,2] 🔗, Frank Fraticelli PhD[2],
Jessica Irizarry PhD[2], Israel Almodóvar-Rivera PhD[3], Martha Nunn DDS, PhD[4] and
Kaumudi J. Joshipura ScD[1,5,6]

[1]Center for Clinical Research and Health Promotion, University of Puerto Rico Medical Sciences Campus, San Juan, Puerto Rico; [2]Department of Public Health, Ponce Health Sciences University, Ponce, Puerto Rico; [3]Department of Mathematical Sciences, University of Puerto Rico at Mayagüez, Mayagüez, Puerto Rico; [4]Nunn Biostatistical Solutions, Omaha, NE, USA; [5]School of Public Health, Ahmedabad University, Ahmedabad, India and [6]Department of Epidemiology, Harvard T. H. Chan School of Public Health, Boston, MA, USA

Original Research

Abstract

Objective: To evaluate the impact of Hurricanes Irma and Maria on 3 major chronic diseases in Puerto Rico.

Methods: San Juan Overweight Adults Longitudinal study participants were re-evaluated after Hurricanes Irma and Maria (May 2019–July 2020) for the Preparedness to Reduce Exposures and Diseases Post-hurricanes and Augment Resilience study. This study compared the prevalence and incidence of asthma, depression, and hypertension within the same 364 individuals over time.

Results: Asthma and depression prevalence and incidence did not change significantly after the hurricanes. The prevalence of hypertension increased significantly after the hurricanes (OR = 2.2, 95% CI: 1.2, 3.9). The incidence of hypertension after the hurricanes (IR = 9.0, 95% CI: 6.5, 12.4) increased significantly compared to before the hurricanes (IR = 6.1, 95% CI: 4.5, 8.0) (age-adjusted incidence rate ratio [aIRR] = 1.4, 95% CI: 4.5, 8.0) for similar time periods.

Conclusion: Hurricanes Irma and Maria were associated with a significant increase in the prevalence and incidence of hypertension in this study population. Contrary to expectations, no significant increases were observed in depression and asthma prevalence after the hurricanes. Results from this study can inform better strategies to prevent and manage hypertension in the population affected by a hurricane.

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The world has been facing a dramatic increase in the number and severity of natural disasters because of global climate change. The 2021 Atlantic hurricane season was the third most active on record in terms of named systems, with 21 named storms.[1] For the 2022 Atlantic hurricane season, predictions indicated there would be 19 named storms, including 9 hurricanes, with 4 of these being major hurricanes (Category 3 or higher).[2] Usually, the health impact of natural disasters is concentrated in the immediate and short-term health consequences. However, there could also be important long-term impacts on health after experiencing a natural disaster.[3] Major hurricanes (eg, Hurricane Sandy in 2012 and Hurricane Maria in 2017) could cause infrastructure damage with loss of power, damaged roads, and disruption of water supply and access to healthy food. These factors could aggravate existing chronic diseases or potentially lead to new chronic diseases.

Every year, 41 million people die worldwide due to non-communicable diseases (NCDs) such as heart attacks, cancer, chronic respiratory diseases, diabetes, and mental disorders.[4] Being physically inactive, smoking, having high alcohol intake, and unhealthy dietary practices are among the behaviors that put people at risk for the development of a chronic condition. In 2019, the Puerto Rico Department of Health (PRDoH) reported that the primary causes of death between 2015 and 2016 were all attributable to chronic diseases.[5]

In 2017, Puerto Rico experienced 2 significant natural disasters that impacted the entire island: Hurricane Irma and Hurricane Maria. On September 6, 2017, Hurricane Irma, a Category 5 storm, passed close to Puerto Rico, causing US $700 million in damages.[6] Two weeks later, on September 20, 2017, Hurricane Maria made its way across Puerto Rico as a Category 4 storm, causing US $100 billion in damages.[6] An estimated 472 000 houses were damaged, and 18% of those were destroyed; the roads were devastated or full of debris, and the impact of critical infrastructure affected the entire population.[7] Health infrastructure such as the Puerto Rico Department of Health laboratories for diagnostic testing and disease surveillance, and health care facilities, were severely damaged as a result of the hurricanes.[7,8] Only 3 major

hospitals were functional 4 days after the hurricanes; however, because of the loss of telecommunications, hospitals, patients, and staff were not able to communicate.[8] Considering Puerto Rico's location and governmental status (an incorporated US territory), help was delayed when compared to similar situations in the contiguous states.[9] As a result, in 2020, Puerto Rico was still in the recovery phase with people still without housing, or living under the blue tarp roofs that they received in 2017 after the hurricane.[10]

Estimates of excess deaths as a result of Hurricane Maria were as high as 4645 (95% CI: 793, 8498).[11] Most excess deaths after Hurricanes Irma and Maria occurred from heart disease, diabetes, Alzheimer's disease, and other causes, which suggested that the majority of the deaths were due to chronic diseases.[12] However, little information is currently available regarding the effect of natural disasters on either the prevalence, incidence, or worsening of chronic conditions as a result of natural disasters. Studies conducted after Hurricane Maria focused on mortality, mental health, and nutrition.[11–16] To date, only 1 study, published in 2022, evaluated the prevalence of chronic diseases before and after Hurricane Maria in Puerto Rico. This study compared participants in 2019, with previous data from where significant differences were found after the hurricanes in the prevalence of hypertension (47.3% vs 39.2%), arthritis (32.3% vs 25.6%), high cholesterol (36.4% vs 23.8%), high triglycerides (23.1% vs 14.7%), fatty liver disease (12.8% vs 7.5%), and osteoporosis (13.9% vs 5.2%).[17] A previous study found that lower pre-hurricane preparedness was associated with hurricane-related detrimental health impact (OR = 1.96; 95% CI: 1.31, 2.95) and development of new NCDs (OR = 2.07; 95% CI: 0.92, 4.68).[18]

Natural disasters are a consistent predictor of adverse health outcomes, including the development or worsening of chronic diseases.[19] Due to the increasing frequency and severity of hurricanes, we need to understand how these disasters affect NCDs, to reduce the adverse health impact of future hurricanes. The study objective was to evaluate longitudinally the impact of Hurricanes Irma and Maria on 3 major chronic conditions in a sample population of Puerto Ricans.

Methods

The aim of the Preparedness to Reduce Exposures and Diseases Post-hurricanes and Augment Resilience (PREPARE) study was to evaluate risk and resiliency factors related to Hurricanes Irma and Maria, focusing on non-communicable diseases.[18] This study was built on data collected across Puerto Rico before the hurricanes, and additional data were collected post-hurricanes among the same participants. Participants free of diabetes, ages 40 to 65 years, overweight or obese and resident in the San Juan municipality and its vicinity, were recruited from the San Juan Overweight Adults Longitudinal Study (SOALS). SOALS evaluated 1351 participants at baseline (between 2011 and 2013), 881 of these completed the 3-year follow-up (between 2014 and 2016), and 869 consented for future studies (377 from San Juan, 281 from the rest of the metropolitan area, and 211 from other areas of Puerto Rico).

Participants who were free of diabetes at the SOALS follow-up visit were eligible for PREPARE. Exclusion criteria included being pregnant; missing data on key components at the SOALS follow-up visit (eg, HbA1c, fasting glucose, BMI, blood pressure, smoking habits, physical activity); having metastatic cancer or cancer treatments such as radiotherapy or chemotherapy at the time; being diagnosed with hypoglycemia, congenital heart murmurs, heart valve disease, genetic heart diseases, heart valve or cardiac

tissue infections (eg, endocarditis) or rheumatic fever; being in active dialysis treatment; having hemophilia or anticoagulant therapy; and having a pacemaker, implanted defibrillator, or any artificial (prosthetic) material in the heart, veins, or arteries. From the 869 SOALS participants who consented to future studies, 364 participants were willing and eligible to participate in the PREPARE study and provided post-hurricane data.

The PREPARE study began approximately 20 months after Hurricanes Irma and Maria hit Puerto Rico. Eligible and willing participants were scheduled for in-person visits and evaluated between May 2019 and July 2020. During in-person visits, the interviewer explained and discussed the informed consent document, which stated the purpose of the investigation, that the participation to the study was voluntary and that participants could withdraw from the study at any time without penalty and could ensure participants' confidentiality by informing the safety measurements implement to maintain records in a designated confidential space and de-identify all the databases. This process also included an eligibility reassessment, answering all participants' questions regarding their participation in the study, obtaining the participants' signatures and consent, and giving them a copy of the signed informed consent. After completing written informed consent and establishing confirmation of eligibility, trained interviewers conducted computer-aided interviews in Spanish, using REDCap. All 4 interviewers had at least completed high school and were trained by experienced investigators who conducted regular oversight to ensure that data collection procedures were performed correctly, and provided feedback as needed. Training consisted of explaining and discussing each question, data entry in the REDCap platform, conducting mock interviews, and providing tips and effective techniques to gather data through interviews.

Puerto Rico experienced a series of earthquakes in January 2020. On March 15, 2020, the government mandated a lockdown due to the coronavirus disease (COVID-19) pandemic. Due to the lockdowns and restrictions related to the pandemic, the decision was taken by the team to drop the 17 pending SOALS participants. The recruitment by location was close to the target (143 from San Juan municipality, 114 from the San Juan Metro, and 101 from other areas of Puerto Rico), over-sampling from San Juan municipality as it had fewer eligible participants from the other 2 regions. This study was approved by the University of Puerto Rico Medical Sciences Campus (protocol number A4840218) and the Ponce Health Sciences University (protocol number 2102053038) Institutional Review Boards.

Data Analysis

A descriptive analysis was conducted. Crude incidence rates and prevalence for each self-reported chronic condition (hypertension, asthma, and depression) with corresponding 95% CI were calculated for each time period before and after the hurricanes. Conditional fixed-effects logistic regression models, which are designed to work with repeated measures, were fit to compare the prevalence of each of the diseases before and after the hurricanes. For the incidence of each outcome, people who developed the diseases prior to each time period were excluded; hence, the participants varied across the 2 time periods and outcomes. Therefore, incidence rate ratios (IRR) comparing incidence before and after the hurricanes were calculated using the generalized estimating equation (GEE) models to adjust for within-person repeated measures and to adjust for age. For the incidence and

Table 1. Sociodemographic characteristics of participants after the hurricanes

Sociodemographic characteristics	N (%)
Age (mean, SD)	58.7 (6.8)
Sex	
Female	280 (76.9)
Male	84 (23.1)
Employment status	
Employed	153 (42.0)
Unemployed	29 (8.0)
Full-time housewife/husband	39 (10.7)
Retired	111 (30.5)
Work disability	32 (8.8)
Annual household income	
Less than US $20 000	175 (48.3)
US $20 000 or more	187 (51.7)
Geographical location	
San Juan	144 (39.6)
Metropolitan	116 (31.9)
Outside	104 (28.6)
Education	
High school diploma or less	95 (26.1)
Associate degree or some university courses	127 (34.9)
Bachelor's degree or more	142 (39.0)
Health insurance	
Private	61 (16.8)
Public	286 (78.6)
None	17 (4.7)
Last medical visit	
<6 months	308 (87.0)
≥6 months	46 (13.0)

prevalence analyses, participants who did not have information about hypertension, asthma, and/or depression were excluded from the statistical analysis of each condition (available case analysis).

Wilcoxon rank-sum test was used to evaluate whether the development of asthma, depression, and hypertension spanning the hurricanes was different across age. This was also evaluated across sex and smoking status using the chi-square test. Since some of the interviews took place after the 2020 earthquakes, which could impact the responses and associations, sensitivity analysis by date of interview was also conducted. However, no significant differences were seen when comparing responses by date of interview. Analysis was conducted using the statistical software of Stata™ 16 (StataCorp, College Station, TX), and the statistical significance was set at 0.05.[20]

Results

Most of the participants were female (76.9%), and the mean age was 58.7 (SD = 6.8; range 46–74) (Table 1). Almost half of the participants (48.3%) had an annual household income less than US $20 000, were employed (42.0%), and the majority had public health insurance (78.6%). More participants were in San Juan municipality (39.6%), whereas the others were almost equally distributed across the metropolitan area (31.9%) and outside of the metro area (28.6%). Fewer participants reported being current smokers after the hurricanes (11.3%) compared to before (18.4%).

The majority of the participants (87.0%) had a regular medical visit in the last 5 months prior to the interview.

Table 2 shows that the prevalence of asthma was 22.8% after the hurricanes compared to 23.6% before the hurricanes (OR = 0.9, 95% CI: 0.4, 1.6). Fourteen participants developed asthma after the hurricanes, incidence rate (IR) 3.0 per 100 person-time year units (95% CI: 1.8, 5.0). Table 3 shows that compared to before the hurricanes (IR = 4.0, 95% CI: 2.8, 5.5), the incidence of asthma after the hurricanes decreased (age-adjusted IRR [aIRR] = 0.8, 95% CI: 0.6, 1.2). There was no difference in the mean age of the participants who developed asthma (59.4 ± 1.9) and those who did not develop asthma (58.3 ± 0.4). No significant difference was found between males and females; however, 6.4% of the females developed asthma compared to 1.4% of the males (data not shown in tables). Only 1 participant who developed asthma was a current smoker (data not shown in tables).

The prevalence of depression was 25.0% compared to 25.6% before the hurricanes (OR = 0.9, 95% CI: 0.5, 1.7). New cases of depression were found in 16 participants. The incidence rate of depression after the hurricanes was 3.4 (95% CI: 2.1, 5.5), compared to 5.0 (95% CI: 3.8, 6.8) before the hurricanes (aIRR = 1.1, 95% CI: 0.8, 1.5). Participants who developed depression were, on average, younger (55.8 ± 0.9) than those who did not develop depression after the hurricanes (59.0 ± 0.5). More females developed depression (6.7%) compared to males (4.6%); however, no adjustment for sex was done as no association was found between depression and sex (data not shown in tables). Among participants who were current smokers, 17.4% developed depression compared to 5.1% among past or never smokers (data not shown in tables).

The prevalence of hypertension was 39.3% before the hurricanes, while after the hurricanes, prevalence increased significantly to 44.8% (OR = 2.2, 95% CI: 1.2, 3.9). A higher number of the participants developed hypertension (n = 35) after the hurricanes (IR = 9.0, 95% CI: 6.5, 12.4). Compared to the period before the hurricanes (IR = 6.1, 95% CI: 4.5, 8.0), the incidence of hypertension after the hurricanes increased significantly (aIRR = 1.4, 95% CI: 4.5, 8.0). Participants who developed hypertension were almost the same age (58.1 ± 1.0) compared to those who did not develop hypertension (57.2 ± 0.5); the sex distribution was also similar in both groups (data not shown in tables). Smoking status was associated with the development of hypertension; among current smokers, 37.5% developed hypertension compared to 13.5% among non-smokers (data not shown in tables).

Limitations

The PREPARE participants were drawn from across Puerto Rico but were restricted to overweight/obese adults ages 46–74 years. Hence, results cannot be generalized to the entire Puerto Rico population as PREPARE study used a convenience sample. Therefore, the prevalence and incidence measures of asthma, depression, and hypertension are not generalizable to all Puerto Ricans. Non-response bias can be seen in this type of study, as participants that may be more affected or are unhealthier will be less willing to participate in a research study. Therefore, this study may not have captured all new cases of these chronic conditions. It is hard to assess the response rate since the PREPARE study aimed to recruit 375 participants, 125 from each of 3 different locations (San Juan, Metro and outside). In terms of the study design, it is important to recognize that the information regarding

Table 2. Prevalence of specific non-communicable disease before and after the hurricanes

Self-reported diseases	Prevalence before the hurricanes % (95% CI)	Prevalence after the hurricanes % (95% CI)	Odds ratio (95% CI)
Asthma	23.6 (19.3, 28.0)	22.8 (18.5, 27.2)	0.9 (0.4, 1.6)
Depression	25.6 (21.0, 30.0)	25.0 (20.6, 29.5)	0.9 (0.5, 1.7)
Hypertension	39.3 (34.3, 44.3)	44.8 (39.7, 49.9)	**2.2 (1.2, 3.9)**

Table 3. Incidence rates[1] of non-communicable diseases before and after the hurricanes

Self-reported diseases	Incidence before the hurricanes (95% CI)	Incidence after the hurricanes (95% CI)	IRR[2] (95% CI)	aIRR[3] (95% CI)
Asthma	3.9 (2.8, 5.8)	3.0 (1.8, 5.0)	1.0 (0.7, 1.3)	0.8 (0.6, 1.2)
Depression	5.0 (3.8, 6.8)	3.4 (2.1, 5.5)	1.0 (0.8, 1.3)	1.1 (0.8, 1.5)
Hypertension	6.1 (4.5, 8.1)	9.0 (6.5, 12.4)	**1.5 (1.2, 1.9)**	**1.4 (1.1, 1.8)**

[1]Incidence rates per 100 person-year unit;
[2]IRR, incidence rate ratio;
[3]aIRR, age-adjusted incidence rate ratio.

hurricane impact was collected 1.5 years after the hurricanes and, in some cases, almost 3 years after the hurricanes (participants were interviewed from May 2019 to March 2020). Recall bias can occur when there is differential misclassification of the study subjects with regard to the exposure, or outcome variable (which may be pertinent here). This type of bias can be reduced by limiting the time period for the interviews (eg, 3 to 5 months after the hurricanes). Verification of self-reported data of the outcome has also been used to avoid recall bias.[21] However, since this study used an existing database, we did not have data from medical records for these outcomes. The misclassification and bias may likely be small as we are accessing major health conditions that people are likely to remember. However, participants may not be aware that they have these conditions or may not want to disclose them. Due to the scope of this research, only 3 main chronic diseases were evaluated, whereas other chronic conditions may have also been influenced following natural disasters. Results from this study are important in understanding the impact of Hurricanes Irma and Maria in Puerto Rico. These results add to existing evidence that natural disasters could have a detrimental impact on the population's health.

Discussion

Natural disasters disrupt the environment and have potential life-threatening effects on the population.[19] Due to global warming, natural disasters will continue to emerge and countries that have never been impacted will suffer catastrophically.[22] A previous study reported that individuals living with NCD during Hurricane Maria faced several challenges managing and getting treatment for their conditions.[23] These challenges resulted in exacerbation of chronic disease and loss of life.[23] Hence, it is important to understand the impact of hurricanes on the development of NCD, to reduce the morbidity and mortality after natural disasters. Results from this study showed no significant difference for asthma and depression; however, hypertension prevalence and incidence increased following the hurricanes.

Common triggers of asthma like dust, mold, high levels of allergens, poor quality of air, cold air, and infections can be seen after natural disasters. Previous studies found that after thunderstorms, asthma admissions were higher than in other days due to an increase in the concentration of mold spores and pollen.[24,25] Even though in PREPARE these conditions were not evaluated, stressful situations like experiencing a natural disaster could also trigger the development of, or worsen, asthma.[26] However, only 14 participants reported developing asthma after the hurricanes, and data showed a reduction in both the prevalence and incidence, which may be due to healthier individuals participating in the study. This could also be due to fewer participants being at high risk and being exposed to asthma risk factors.

After experiencing major life changes or trauma, people are more vulnerable to developing depression.[27] Since depression is a major burden in the general population, it is the most prevalent mental health disorder post-disasters.[27] Previous studies have found that environmental stressors increase the prevalence of depression.[28,29] However, depression results were similar before and after the hurricanes for both the prevalence and incidence, with only 16 participants developing depression after the hurricanes. It is important to note that while the individual incidences of depression may seem to differ before and after the hurricane, the GEE model results show that the incidence of new cases of depression before and after the hurricanes was similar. Results for depression are not consistent with these studies, since no significant number of new cases after the hurricanes was seen. Depression is a behavioral condition that affects the mood of the individual; therefore, it is expected that participants are less willing to participate in research studies if they develop this condition, which could explain why the incidence and prevalence of depression were lower after the hurricanes. Another explanation for this can be resilience. Resilience is "bouncing back" from difficult experiences, such as a natural disaster, and it implies a process of adapting well in the face of adversity, trauma, tragedy, threats, or significant sources of stress.[30] After Hurricane Maria, there were many instances when Puerto Ricans took matters into their own hands. For example, when people saw that help was delayed, they started to help their community by cleaning the road debris and helping their neighbors with water, food, gasoline, and roof tarps.[31]

The hypertension results from this study align with a previous systematic review and meta-analysis, which found that following natural and man-made disasters, the prevalence of hypertension was higher among survivors of disasters compared to the general

population.[32] A previous study reported that following a natural disaster, psychological stress and environmental changes can influence the development of hypertension.[33] Hypertension is a serious condition, as high blood pressure can damage the arteries by making them less elastic and decreasing the blood and oxygen flow to the heart, which could lead to heart disease, stroke, and other conditions.[34] Therefore, it is important to acknowledge the implications of natural disasters in the development and progression of hypertension, which if left untreated could lead to other complications. In the context of natural disasters, the food available is often non-perishable and contains high levels of sodium, which can lead to high blood pressure. In addition, it is often difficult to access fresh vegetables, fruits or meat, due to a lack of electricity and transportation.

Conclusion

After a natural disaster, the medical attention is often concentrated on treating acute injury and illness, leaving fewer resources to prioritize chronic conditions prevention and management.[35] Chronic disease incidence after a disaster is an understudied research priority.[36] While previous research in Puerto Rico in the context of Hurricanes Irma and Maria has focused on mortality, injuries, mental health, and nutrition, results from this study demonstrate that there is also a need to evaluate and plan for chronic diseases in this context.[11–16,36,37] Understanding the impact that natural disasters, like hurricanes, exert on the health of populations with chronic conditions or those at high risk of developing NCDs will help inform further efforts. The information obtained from this study is useful to develop better preparedness strategies from a public health perspective. It can also inform policies and can be used to advocate for better planning in emergency situations.

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