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Assessing HIV Care Outcomes Among Persons Who Use Drugs in Puerto Rico Before and After Hurricane Maria

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Abstract

Objectives: To explore the health impacts of Hurricane Maria (HM) on HIV care outcomes among people living with HIV who use drugs.

Methods: Using data from an ongoing cohort study in San Juan, Puerto Rico (Proyecto PACTo), we measured differences in HIV care outcomes (viral load, viral suppression, and CD4 counts) before and after HM using assessments conducted at 6-month intervals. Generalized estimating equations were used to assess factors associated with HIV care outcomes.

Results: All HIV care outcomes showed a deterioration from pre-HM values to post-HM values (mean viral load increased, CD4 counts decreased, and rate of viral suppression decreased) after controlling for pre-HM sociodemographic and health characteristics. In addition to HM, age (aIRR = 1·01), being homeless (aIRR = 0·78) and having health insurance (aIRR = 1·6) were independently associated with viral suppression.

Participants: 219 participants completed follow-up visits between April 2017 and January 2018, before and after HM.

Conclusions: People living with HIV who use drugs in Puerto Rico experienced poorer HIV outcomes following HM. Socio-environmental factors contributing to these outcomes is discussed in the context of disaster response, recovery, and program planning.

Original Research

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Keywords:
extreme weather; HIV care outcomes; Hurricane Maria; Puerto Rico; substance use; vulnerable populations

Abbreviations:
aIRR, annualized incidence rate ratio; AUDIT, Alcohol Use Disorders Identification Test; CAPI, computer-assisted personal interview; CD4, cluster of differentiation 4; CES-D, Center for Epidemiologic Studies Depression Scale; CI, confidence interval; DAST-10, Drug Abuse Screening Test; DSM-IV, Diagnostic and Statistical Manual of Mental Disorders; FEMA, Federal Emergency Management Agency; GEE, generalized estimating equation; HCSUS, HIV Cost and Services Utilization Study; HIV, human immunodeficiency virus; HM, Hurricane Maria; HRPO, Human Research Protection Office; IRB, Institutional Review Board; IRR, incidence rate ratio; MSA, Metropolitan Statistical Area; NIH, National Institutes of Health; PTSD, posttraumatic stress disorder; PVL, plasma viral load

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In 2017, Puerto Rico was heavily impacted by Hurricane Maria (HM). Beyond extensive property damage and a power outage of historic proportion, HM had an exacting human toll. The storm severely limited access to electrical power, food, clean water, sanitary conditions, safe housing, transportation, schooling, health, and social services.[1] The number of excess deaths following HM is estimated to be between 1190 and 4645, with 1/3 attributed to health care delays or interruptions.[2,3] The storm further compromised an already-troubled health care infrastructure.[4] According to the Health Resources and Services Administration, almost half of all island residents lived in an area with a health care provider shortage, which increased 10-fold following the storm.[4] In addition to the departure of many medical providers, medical facility closures and limited operations were common due to property damage, power outages, and medical supply shortages. Post-HM, electronic prescriptions took significantly longer to return to pre-HM numbers than after Hurricane Harvey in Texas and Irma in Florida, which occurred during the same hurricane season as Maria.[5] While existing literature has exposed the storm's impacts and health care gaps on those who were particularly vulnerable,[6,7] Maria's burden on people living with HIV/AIDS and people who use drugs has yet to be examined.

Previous research has explored disruptions in clinical care caused by other disasters. For people contending with chronic illness such as HIV, these care interruptions can result in long-term health challenges and increased community-level risk of transmission. In the aftermath of Hurricane Katrina, for example, people who use drugs reported increases in substance use risk[8] and HIV/HCV risk behavior patterns.[9] People living with HIV who presented with posttraumatic stress disorder (PTSD) symptoms after Katrina were more likely to experience an increase in negative health outcomes associated with HIV.[10]

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Prior to HM, Puerto Rican people living with HIV who use drugs were already living in a "layered risk environment" mired with social disadvantages and challenges across the care continuum.[1,11] Previous research identified individual- and socio-structural level factors and processes such as transience, social isolation, stigma, limited housing options, and inadequate medical and substance use disorder treatment services that negatively affected HIV/HCV risk among people who use drugs on the island.[11] According to HIV surveillance data, people who use drugs in Puerto Rico are the least likely subpopulation to be linked to medical care. From 2007–2013, HIV-related deaths in the San Juan metro area were greatest among men and people who use drugs. San Juan-based people living with HIV who use drugs are among those most likely to encounter barriers to having urgent medical needs met.[12] Patient treatment access has been further complicated by (1) limited transportation options; (2) diminished institutional memory driven by high turnover in government agencies; and (3) a dwindling number of health care providers, many of whom exited the island in the wake of Puerto Rico's financial crisis preceding the hurricanes.[13,14]

The present study sought to understand the impact of HM on a cohort of people who use drugs who were living with HIV/AIDS. As previous literature has demonstrated, natural disasters have an intersectional impact on mental health and HIV care outcomes; we hypothesized that HM would have negative consequences for Puerto Rico's vulnerable population of people living with HIV who use drugs. We sought to uncover how this population fared by evaluating biological, psychological, and social outcomes prior to and following HM. We then discuss our findings' potential implications for future HIV, mental health, and disaster research.

Methods

Parent Study and Participants

Project PACTo recruited a cohort of 409 people living with HIV who use drugs from 5 study areas within the San Juan Metropolitan Area (MSA) between 2014 and 2016. The study employed a randomized roll-out design[15] in which each study area was randomly assigned to a specific time at which a community-based intervention of HIV testing, linkage to HIV care services, and delivery of basic care services was implemented. Study participants were recruited from 3 settings within each study area: (1) community settings; (2) syringe services programs; and (3) substance use treatment centers. Potential participants completed the informed consent process prior to participation. Eligibility criteria included (1) being HIV-seropositive (verified by an HIV rapid test) and (2) reporting any drug and/or heavy alcohol use within the past 12 months. At baseline and every 6 months thereafter, participants provided a blood sample to measure viral load and CD4 counts and completed a social and behavioral assessment through a computer-assisted personal interview (CAPI).

Data Collection and Measures

The present analysis includes available data from all participants who completed at least one 6-month follow-up visit before and after the hurricane's landfall on September 20, 2017; the majority of the visits occurred from April 2017 to January 2018. During the 6-month intervals, CAPI was conducted to obtain participants' self-reported information.

Sociodemographics

Sociodemographic measures collected included demographics (eg, age, gender), socio-economic factors (eg, income, health insurance, housing status, and education), history of incarceration, and whether respondents lived in the mainland US pre- and post-HM. Respondents reported experiences of homelessness and areas in which they spent the most time in the past 6 months. In order to ascertain whether non-participation in the study increased due to ill health or death post-HM, attrition was calculated for all participants.

HIV Clinical Assessments

Blood serum samples from all participants were collected by a study nurse and analyzed by local laboratories to evaluate HIV outcome measures (viral load and CD4 count). Viral suppression was measured as a binary variable: plasma HIV viral load (PVL) </= 200 copies/mL.[16] Access to care was assessed with a scale that was validated for and used in English and Spanish in the HIV Cost and Services Utilization Study (HCSUS), a benchmark health services study of people living with HIV from across the US.[17] The scale includes the following statements: (1) "If I need hospital care, I can get admitted without any trouble"; (2) "It is hard for me to get medical care in an emergency"; (3) "Sometimes I go without the medical care I need because it is too expensive"; (4) "I have easy access to medical specialists I need"; (5) "Places where I can get medical care are easy to get to"; and (6) "I am able to get medical care whenever I need it." Medication adherence was assessed by asking participants the percentage of HIV medication taken in the past month.[18]

Substance Use Behaviors

Drug use severity was measured using the Drug Abuse Screening Test (DAST-10).[19] Substantial severity was indicated by a DAST-10 score greater than or equal to 6. Hazardous drinking was defined as moderate alcohol misuse based on the Alcohol Use Disorders Identification Test (AUDIT). Scores greater than or equal to 8 are indicative of hazardous and harmful alcohol use and possible alcohol dependence.[20] Illicit drug use included any use of marijuana, crack cocaine, powder cocaine, heroin and cocaine, and heroin in the past 6 months.

Mental Health and Psychosocial Factors

Depression was assessed by the Centers for Epidemiologic Studies–Depression (CES-D) scale.[21] Respondents were asked to rate the frequency with which they experienced 20 depressive symptoms in the past week. Ordinal response choices ranged from 1 ("rarely or none of the time; less than 1 day/week") to 4 ("most or all of the time; 5–7 days/week"). The items are compatible with the Diagnostic and Statistical Manual of Mental Disorders' (DSM-IV) criteria for depression. A score of 16 or greater suggests a high level of depressive symptoms.

Respondents answered 5 questions to capture the different types of social support they had received in the past 4 weeks. Response choices ranged from 1 ("none of the time") to 5 ("all of the time").[22,23] We used the sum of the responses to the 5 questions in the analysis.

Also included were 2 questions on conflictual social interaction[23] that have been previously used to assess social interactions, support, and mood among people living with HIV. Problems were assessed in the past 4 weeks, and respondents were asked about

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having disagreements and arguments with family or friends about things that were important to them. Response choices ranged from 1 ("none of the time") to 5 ("all of the time"), and respondents' average scores were used to reflect conflictual social interaction. The physical abuse/interpersonal violence scale was adapted from a previous study to capture the total number of events of physical abuse or interpersonal violence in the past 6 months.[24]

Service Utilization

This study measured service utilization based on self-reported health care service use in the past 6 months, including number of nights in the hospital, number of clinic/outpatient visits, community clinic visits, and number of doctor visits. Responses were dichotomized to "yes" or "no," where *yes* indicated any use of health care services in the past 6 months.

Food and Energy Security

Food security was measured by the amount of food a participant ate and the number of days a participant had no food, or money to buy food, in the past 4 weeks.[25] This measure was dichotomized so that 1 indicated a respondent had enough to eat and 0 indicated that there was not enough food to eat (ie, sometimes, often not enough). The number of days a participant had not had food was dichotomized as 1 if there were zero days of no food and 0 if there were one or more days without food. One question was included regarding participants' energy, which was similarly dichotomized such that 1 indicated they always had energy, and 0 indicated not enough energy.

Statistical Analysis

We used descriptive statistics to characterize the study population pre- and post-HM. We used modified Poisson regression with robust error variance and an unstructured correlation structure to compare pre- and post-HM changes in (1) viral suppression; (2) homelessness in the past 6 months; (3) substance use in the past 6 months (severe drug use, types of illicit drug use, and hazardous drinking); and (4) depression. Generalized estimating equation (GEE) models with a Gamma link and an unstructured correlation structure were used to compare changes in viral load (log10-transformed), whereas negative binomial GEE models with a log link and an unstructured correlation structure were used to compare changes in (1) CD4 counts; (2) physical abuse/interpersonal violence; (3) access to care; (4) social support; (5) conflictual social interactions; (6) medication adherence; and (7) service utilization pre- to post-HM. To further examine the association with HM and HIV outcomes for people living with HIV who had different levels of viral suppression prior to HM, we stratified our analysis by participants who were virally suppressed versus not virally suppressed pre-HM. All GEE models included HM as the main effect and controlled for pre-HM sociodemographic variables as covariates. We calculated incidence risk ratios (IRRs) with 95% confidence intervals (CIs) and P values $< 0{\cdot}05$ for 2-sided tests. Analyses were performed using SAS 9·4 statistical software package (SAS Institute, Cary, NC, USA). Pre- and post-HM assessments reported herein were done after the intervention was implemented in all neighborhoods, and thus we did not control for the intervention in the statistical models.

Institutional review

This study was approved by the Human Research Protection Office (HRPO) Institutional Review Board (IRB) of Columbia University (Protocol-AAAK8805) and The University of Puerto Rico (Protocol-1680613).

Results

Demographics

A total of 219 of the 409 cohort participants completed follow-up visits within both the 9-month period before and after HM, as shown in Table 1. Of the 190 participants who did not complete a study visit within the 9-month period around HM, 70% (132/190) dropped out in the first 2 waves of the study in early 2015, which was more than 2 years prior to HM. In addition, 47% (n = 89) were lost to follow-up due to death, before the hurricane hit.

The mean age at pre-HM was 47 years (SD = 8·8), and the sample was predominantly men (74%). Most had at least a high school education (67%) and reported an annual income of equal to or less than USD $5000 (89%). About 1/3 (34%) of the sample was homeless and 76% of participants had a history of incarceration. Participants were recruited from the San Juan metropolitan area; their neighborhood of reference did not change after the storm. The majority of participants had health insurance (88%), mostly government-issued, and more than half (55%) had resided in the mainland US at some point in their lifetime. Participants used a variety of substances, including marijuana, heroin, and cocaine, though no significant changes in substance use or severe drug use were reported pre-HM and post-HM.

Overall Changes Pre- and Post-HM

Changes in HIV clinical outcomes pre- and post-HM are presented in Table 1. The mean post-HM viral load was 2·32 log10 copies/ml (SE = 0·09), significantly higher than the average viral load pre-HM (2·10 log10 copies/ml, SE = 0·08; $P = 0{\cdot}001$). CD4 counts were lower post-HM (mean = 552·65 cells/μl, SE = 23·06) compared to pre-HM (mean = 588·08 cells/μl, SE = 24·67) ($P = 0{\cdot}006$) (Figure 1). Pre-HM, viral suppression (</= 200 copies/ml) was 71% compared to 65% post-HM. There were no significant differences pre- and post-HM in the most recent HIV primary care visit; more than 90% of participants had a visit within the past 3 months. In addition, we also examined the changes in antiretroviral (ARV) regimens pre- and post-HM; 32% (69/219) of participants had a change in regimens. More than half of the participants reported never missing any medication in the past month (53% for pre- and 55% for post-HM); there were no significant differences pre- and post-HM.

After controlling for demographic, social, and behavioral covariates (age, gender, income, health insurance, incarceration history, homelessness, history of living in the mainland US, severe drug use, and depression), there was a 9% reduction in viral suppression between pre- and post-HM (aIRR = 0·91, 95% CI: 0·85-0·99, $P = 0{\cdot}02$). In addition to HM, age (aIRR = 1·01, 95% CI: 1·00-1·02), homelessness (aIRR = 0·78, 95% CI: 0·62-0·98), and having health insurance (aIRR = 1·6, 95% CI: 1-2·57) were all independent predictors of viral suppression. The access to care scale demonstrated a 22% reduction post-HM compared to pre-HM (IRR = 0·78, 95% CI: 0·66-0·92, $P = 0{\cdot}003$).

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Table 1. Pre- and post-Maria sociodemographic, behavior, and HIV care characteristics (San Juan, Puerto Rico; April 2017–January 2018)

		Demographics	%	Pre-HM	%	Post-HM	%	IRR (ref = Pre-HM) 95% CI
Sociodemographic								
Age (mean, SD)		47·4	8·8					
Gender:	men	162/219	74%					
Income:	≤$5000	196/219	89%					
Health insurance		192/219	88%					
Education (high school or higher)		146/219	67%					
Ever incarcerated		166/219	76%					
Severe drug use in the past 6 months (DAST10 ≥ 6)		96/219	44%					
History living in the mainland US		118/215	55%					
Homeless in the past 6 months				31/219	14%	40/219	18%	1·29 (0·97, 1·72)
HIV clinical assessments								
Viral suppression				153/216	71%	141/218	65%	**0·91 (0·85, 0·99)**
Viral load (mean, SE), log10 copies/ml				2·1	0·1	2·3	0·1	**1·11 (1·04, 1·17)**
CD4 (mean, SE), cells/ul				588·1	24·7	552·7	23·1	**0·94 (0·9, 0·98)**
Access to care				4·4	4·1	3·4	4·0	**0·78 (0·66, 0·92)**
Medication (%) taken in the past month				8·9	2·5	9·0	2·2	1·01 (0·96, 1·06)
Substance use behaviors								
Severe drug use in the past 6 months (DAST10 ≥ 6)				48/219	22%	41/219	19%	0·85 (0·68, 1·07)
Illicit drug use in the last 6 months				105/219	48%	105/219	48%	1 (0·87, 1·15)
	Marijuana			42/219	19%	42/219	19%	1 (0·77, 1·29)
	Crack cocaine			18/219	8%	14/219	6%	0·78 (0·49, 1·23)
	Powder cocaine			13/219	6%	11/219	5%	0·85 (0·44, 1·63)
	Heroin and cocaine			39/219	18%	40/219	18%	1·03 (0·83, 1·27)
	Heroin only			8/219	4%	6/219	3%	0·75 (0·31, 1·83)
Hazard drinking (AUDIT10 ≥ 8)				28/219	13%	37/219	17%	1·32 (0·9, 1·93)
Most Recent HIV primary care visit								
0-3 months (ref)				181/199	91%	179/194	92%	
More than 3 months				18/199	9%	15/194	8%	0·85 (0·44, 1·65)
Mental health								
Depression				106/219	48%	98/219	45%	0·92 (0·78, 1·09)
Physical abuse/interpersonal violence (mean, SE)				1·8	2·1	1·7	2·1	0·97 (0·9, 1·04)
Social support				19·2	6·6	19·6	6·4	1·02 (0·97, 1·07)
Conflictual social interactions				2·8	1·8	2·7	1·6	0·94 (0·84, 1·04)
Service utilization in the past 6 months								
	Number of nights in the hospital			1·2	5·1	1·6	6·3	1·34 (0·61, 2·97)
	Number of hospital clinic/outpatient department clinic visits			1·4	3·9	2·0	4·8	1·47 (0·99, 2·19)
	Number of community clinic visits			0·7	1·6	0·5	1·3	0·68 (0·41, 1·12)
	Number of private doctor visits			0·0	0·2	0·0	0·4	2·01 (0·25, 16·06)
	Number of overall doctor visits			2·2	5·0	2·5	4·8	1·13 (0·87, 1·47)
Food and energy security								
Energy:	always			83/219	38%	72/219	33%	0·87 (0·69, 1·08)
Food security:	enough			188/219	86%	193/219	88%	1·03 (0·96, 1·09)
Number of days with no food:	0 days			180/219	83%	187/219	85%	1·03 (0·97, 1·12)

Changes Stratified by Pre-HM Viral Suppression Status

Participants who were not virally suppressed pre-HM had significantly lower access to care (aIRR = 0·73, 95% CI: 0·55-0·97) and lower medication adherence (aIRR = 0·86, 95% CI: 0·77-0·98) observed post-HM compared to those of pre-HM. The number of hospital/clinic/outpatient visits (aIRR = 1·71, 95% CI: 1·02-2·88) post-HM was greater than that of pre-HM (Table 2). They also reported fewer conflictual social interactions after the storm compared to pre-HM (aIRR = 0·84, 95% CI: 0·73-0·98).

Participants who were virally suppressed pre-HM showed significantly unfavorable HIV care outcomes (viral load and CD4) post-HM and had reduced access to care compared to pre-HM (see Table 2). Overall, they experienced a 24% increase in viral load (log10 VL) (aIRR = 1·24, 95% CI: 1·15-1·34) and a 7% reduction in CD4 counts (aIRR = 0·93, 95% CI: 0·89-0·98)

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Table 2. Pre- and post-Maria demographic and HIV care characteristics by viral suppression Pre-HM (San Juan, Puerto Rico; April 2017–January 2018)

	Not virally suppressed Pre-HM (n = 63)	Virally suppressed pre-HM (n = 153)
	IRR (ref = pre-HM) 95% CI	IRR (ref = pre-HM) 95% CI
Homeless in the past 6 months	1·24 (0·92, 1·68)	1·5 (0·71, 3·17)
Severe drug use in the past 6 months (DAST10 ≥ 6)	0·86 (0·61, 1·2)	0·83 (0·58, 1·19)
Illicit drug use in the last 6 months	1·03 (0·85, 1·23)	0·98 (0·81, 1·2)
Marijuana	0·77 (0·46, 1·29)	1·1 (0·82, 1·48)
Crack cocaine	1·14 (0·73, 1·8)	0·6 (0·27, 1·34)
Powder cocaine	1 (0·3, 3·32)	0·88 (0·4, 1·92)
Heroin and cocaine	1 (0·75, 1·34)	1 (0·71, 1·41)
Heroin only	1 (0·38, 2·66)	0·5 (0·09, 2·73)
Hazard drinking (AUDIT10 ≥ 8)	1·1 (0·51, 2·38)	1·44 (0·94, 2·21)
HIV clinical assessments		
Viral load, log10 copies/ml	0·98 (0·9, 1·06)	**1·24 (1·15, 1·34)**
CD4, cells/ul	0·99 (0·89, 1·11)	**0·93 (0·89, 0·98)**
Access to care	**0·73 (0·55, 0·97)**	**0·81 (0·66, 1)**
Medication (%) taken in the past month	**0·86 (0·77, 0·98)**	1·04 (0·99, 1·1)
Mental health		
Depression	0·87 (0·61, 1·22)	0·97 (0·81, 1·17)
Physical abuse/interpersonal violence	0·88 (0·7, 1·09)	0·98 (0·92, 1·05)
Social support	1·05 (0·96, 1·15)	1·01 (0·96, 1·07)
Conflictual social interactions	**0·84 (0·73, 0·98)**	1 (0·88, 1·13)
Service utilization in the past 6 months		
Number of nights in the hospital	2·46 (0·53, 11·5)	1·01 (0·39, 2·65)
Number of hospital clinic/outpatient department clinic visits	**1·71 (1·02, 2·88)**	1·43 (0·9, 2·26)
Number of community clinic visits	0·41 (0·13, 1·24)	0·74 (0·43, 1·28)
Number of private doctor visits	–	2·01 (0·25, 16·1)
Number of overall doctor visits	1·22 (0·86, 1·73)	1·12 (0·82, 1·51)
Food and energy		
Energy	0·86 (0·6, 1·25)	0·84 (0·64, 1·1)
Food security	1·06 (0·92, 1·22)	1 (0·94, 1·07)
Number of days with no food	1·11 (0·95, 1·3)	1 (0·93, 1·08)

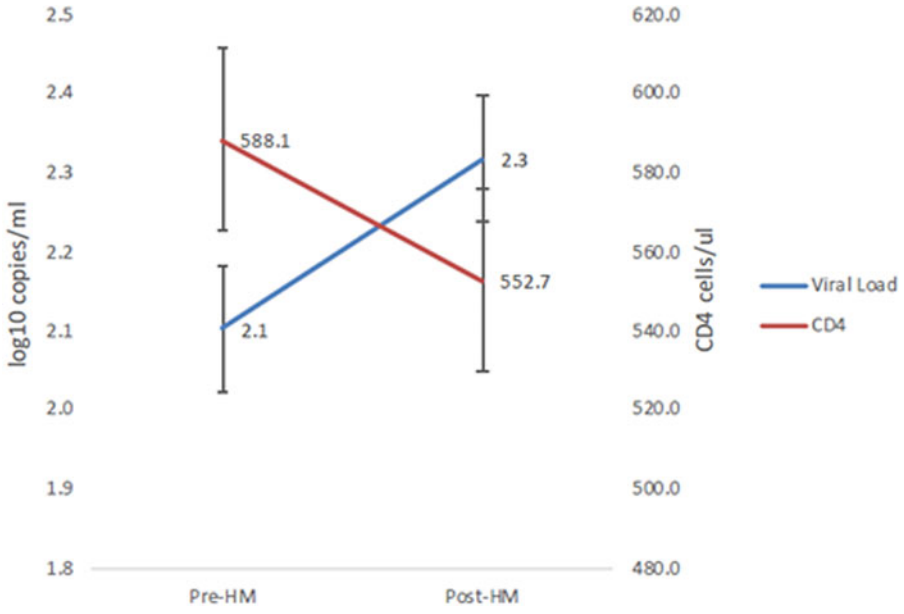

Figure 1. Viral load (log10 copies/ml) and CD4 count (CD4 cells/ul) pre- and post-HM, San Juan, Puerto Rico, April 2017 to January 2018.

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from pre- to post-HM. Virally suppressed participants also faced a reduction in access to care (aIRR = 0·81, 95% CI: 0·66-1·00) from pre- to post-HM.

No significant association was found between HM and increased homelessness, severe drug use, illicit drug use, hazardous drinking, depression, abuse/interpersonal violence count, death, other service utilization, or energy and food security in the past 6 months for participants, regardless of their viral suppression status pre-HM.

Discussion

This is among the first studies to assess the impact of an extreme weather event on social and health outcomes among people living with HIV and people who use drugs. HM was among the deadliest storms in recent history in the US, and our study demonstrates a moderate decrease in the CD4 count experienced in the post-HM period and a decrease in viral load suppression. Our results indicate worsening biological, health care, and social outcomes for people living with HIV who use drugs in Puerto Rico after HM. Study participants experienced increased viral loads and declines in viral suppression and CD4 counts, subjecting them to greater personal risk and higher HIV transmissibility. However, it should be noted that changes in biologic outcomes, while statistically significant, may not be clinically relevant. For example, there was a decrease in the viral suppression rate pre- and post-HM, but given the low-level viremia in this population, it may be explained by persistent viremia, lack of virologic response, and/or HIV drug resistance in the long term.

Moreover, this population experienced marked declines in access to care with over 1/5 of all participants reporting reduced access to care post-HM. Overall, those who were initially virally suppressed experienced declines in HIV outcomes, whereas those who were *not* virally suppressed prior to the storm had aggravated circumstances post-HM such as reduced medication adherence and more hospital/clinic visits, suggesting greater acute care needs. Indicators of vulnerability, such as older age, homelessness, and health insurance status, were significant predictors of HIV outcomes related to viral suppression; however, neighborhood, substance use behavior, and social support were not predictive of such outcomes. Whereas HIV outcomes were negatively associated with the storm, mental health indicators (eg, depression, interpersonal violence) were unchanged.

Disaster literature has often highlighted the mental health impacts of extreme weather events, noting that disadvantaged community members are more impacted by PTSD, depression, and anxiety.[26] In Puerto Rico post-HM, the general population has presented with exacerbated mental health symptomology, including depression, anxiety, PTSD, and suicidality.[1,27,28] This varies considerably from our results, which did not demonstrate significant changes in mental health status before and after the storm. We posit that this may be a result of our study participants' preexisting conditions. The study sample was primarily middle-aged men living with HIV who use drugs. Most were low-income and many were homeless or precariously housed. There were no changes in residential status as a result of the storm; therefore, even though few were displaced, many may have been impacted by long-term power outages, food and gas shortages, poor water quality, and other encumbrances that followed the storm. However, in comparison to more privileged groups, many members of our study had been exercising resilience in navigating life on the margins of society and contending with poverty and stigma associated with living with HIV and substance use. Employing resilience on a daily basis requires psychological faculties that were activated prior to the storm, thereby potentially serving as a buffer against further mental strain.[29]

Beyond what was not evident in the psychological effects of the storm, we did observe strong and adverse biological impacts related to HIV viral load and indicators of viral suppression. We leveraged an existing cohort study to provide these results and view this as an important avenue for future research on the impacts of climate change on medically and socially vulnerable populations.

Limitations

Limitations of this study include the reliance on self-reported measures (eg, interpersonal violence, access to care, social support). Nonetheless, the measures used in this study have demonstrated validity and reliability and were used in conjunction with biological measures of HIV outcomes. Additionally, at the point of data collection for these assessments, some respondents had been participating in the study for over 3 years and developed a rapport with the study team, thereby increasing the likelihood of trustworthy responses. We were not able to examine outcomes by severity of storm impact as impact was quite uniform in the San Juan area. Last, we were not able to establish causality regarding the relationship between HM and HIV outcomes given that we do not have a control group of participants who did not experience HM. However, in the sensitivity analysis, we were able to compare changes between 2017 and 2018 and changes between 2015 and 2016 for the same people who were impacted by HM. From 2015 to 2016, the viral suppression actually increased from 63% (126/200) to 67.6% (146/216), whereas from 2017 to 2018, the viral suppression increased from 66% (144/218) to 69.9% (153/219). Both were better compared to the pre- and post-HM (71% pre-HM to 65% post-HM).

Conclusions

Not only has the incidence of natural disasters such as hurricanes and earthquakes increased in frequency and severity in recent decades, but also their impact on health has been especially pronounced for vulnerable populations around the world. Our results suggest that climate change patterns should require updates to HIV care guidelines to include disaster contingencies. Agencies' pre- and post-disaster plans should include attention to health care to lessen potential care disruption, particularly for vulnerable populations, such as people who use drugs and people living with HIV.[6] Provider migration from disaster zones remains a challenge and should be addressed in future research, disaster, and pandemic preparedness plans.[30] These plans should include further resources for current and future health professionals, including incentives to increase their retention in areas with vulnerable populations. For example, the Latino Medical Student Association of Puerto Rico launched an emergency task force to help medical students meet basic needs in HM's aftermath.[30] Research, however, suggests that this is a point in the system that needs centralization and resourcing, particularly to connect health care students in disaster zones to temporary host institutions.[30] On a larger scale, the federal response for relief and recovery following Maria was robust, but a confluence of economic shocks and various setbacks has impeded spending and resource allocation on the island.[31]

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Climate-related disasters place an additional burden on an already strained health care ecosystem. Recent climate trends indicate that these challenges will likely be more pronounced as climate change worsens.[32] Yet, with further research, preparation, and resources (eg, budget allocation and collaboration between federal agencies such as FEMA, Centers for Disease Control and Prevention (CDC), Health and Human Services (HHS) agencies and offices, and local public health and community partners, NIH), we can progress with lessons learned from HM. The primary lesson stemming from the present research is that disaster contingency plans should be in place with systematic training so that patients, providers, and relief efforts can quickly mitigate care interruptions. Adding protective factors to help diminish disaster effects and increase care outcomes could prove an effective start.

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Competing interest. We declare no competing interests.

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