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The effect of Hurricane Katrina on the prevalence of health impairments and disability among adults in New Orleans: Differences by age, race, and sex

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ABSTRACT

We examined the effects of Hurricane Katrina on disability-related measures of health among adults from New Orleans, U.S.A., in the year after the hurricane, with a focus on differences by age, race, and sex. Our analysis used data from the American Community Survey to compare disability rates between the pre-Katrina population of New Orleans with the same population in the year after Katrina (individuals were interviewed for the study even if they relocated away from the city). The comparability between the pre- and post-Katrina samples was enhanced by using propensity weights. We found a significant decline in health for the adult population from New Orleans in the year after the hurricane, with the disability rate rising from 20.6% to 24.6%. This increase in disability reflected a large rise in mental impairments and, to a lesser extent, in physical impairments. These increases were, in turn, concentrated among young and middle-aged black females. Stress-related factors likely explain why young and middle-aged black women experienced worse health outcomes, including living in dwellings and communities that suffered the most damage from the hurricane, household breakup, adverse outcomes for their children, and higher susceptibility.

Introduction

Hurricane Katrina struck New Orleans, Louisiana, U.S.A. on August 29, 2005. The hurricane itself, widespread flooding due to the failure of the city's levees, and the subsequent displacement and resettlement of the population together had a major effect on the health of the city's inhabitants. More than six years after the disaster, however, there remain important gaps in knowledge about the effects of Katrina on the health of the New Orleans population and, in particular, on health disparities. We used data on adults from New Orleans in the year after the hurricane from the American Community Survey (ACS) to examine the effects of Hurricane Katrina on disability-related measures of health—a dimension of health that has not been examined previously. We focused on differences in disability by age, race, and sex.

Studies to date have focused almost exclusively on the effects of the disaster on mental health and, to a much lesser extent, mortality. In the immediate aftermath of Katrina, studies found that displaced residents from New Orleans experienced high rates of psychological distress (Brodie, Weltzien, Altman, Blendon, & Benson, 2006; Elliott & Pais, 2006; Norris et al., 2006). These initial results were verified by larger-scale and better-designed studies that also documented large disparities in the prevalence of mental illness between blacks and whites (Galea et al., 2007; Kessler, Galea, Jones, & Parker, 2006; Sastry & VanLandingham, 2009). Comparisons of pre- and post-Katrina mental illness for the same individuals—which was possible for several specific groups, including community college students (Rhodes et al., 2010) and the local Vietnamese-American community (Norris, VanLandingham, & Vu, 2009)—have provided additional evidence for the strong negative effects of the disaster on mental health. The most recent set of studies has found continuing high rates of mental illness among individuals affected by Katrina, with only modest declines in mental illness over the subsequent years (Kessler et al., 2008; Paxson, Fussell, Rhodes, & Waters, 2012).

The small number of studies that have examined the mortality effects of Hurricane Katrina have found significant increases in deaths in the aftermath of the disaster, with the mortality effects concentrated among the elderly and among blacks (Brunkard, Namulanda, & Ratard, 2008; Jonkman, Maaskant, Boyd, & Levitan, 2009; Sharkey, 2007; Stephens et al., 2007). Estimates suggest that

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approximately 40% of deaths were due to drowning, 25% to injury and trauma, and 19% to unspecified Katrina-related causes (Brunkard et al., 2008). A challenge these studies encountered was the lack of complete and accurate data on all individuals who died as a result of the hurricane because of reporting problems (caused, in part, by the hurricane itself), migration away from the area, and the absence of detailed covariates on decedents and the population at risk.

Finally, there have been a few studies that have examined Hurricane Katrina's effect on other dimensions of health, such as morbidity or disability. A major shortcoming of these studies is their focus on select population groups—such as enrollees in a Medicare Advantage health plan (Burton et al., 2009; Uscher-Pines, Vernick, Curriero, Lieberman, & Burke, 2009), patients who visited particular health clinics (e.g., Gautam, Menachem, Srivastav, Delafontaine, & Irimpen, 2009; Jiao et al., 2012), non-random samples of residents of trailer parks (Lu, 2011), or small convenience samples (e.g., Chen et al., 2007; Kim, Plumb, Gredig, Rankin, & Taylor, 2008). However, the findings suggest that there were higher levels of disability, an increase in adverse health outcomes, and poorer access to health care in the aftermath of Katrina.

Based on these existing research findings, we hypothesize that Hurricane Katrina had a deleterious effect on several related dimensions of impairment and disability among adults from New Orleans. An increase in mental impairments likely accompanied the high rate of psychological distress experienced by this population. Physical impairments may have risen due to the effects of factors associated with mortality—such as injuries—as well as declines in physical health due, for instance, to the experience of post-disaster stress. Finally, major disruptions in the continuity of care among susceptible individuals, such as those with preexisting chronic diseases or conditions, may have led to a decline in physical health and an increase in impairments and disability.

Our analysis is based on data from the ACS and exploits the study's continuous design and national coverage to compare disability rates between the pre-Katrina population of New Orleans with the same population in the year after Katrina who were interviewed for the study even if they relocated away from the city. The comparability between the pre- and post-Katrina samples was enhanced by the construction and use of propensity weights.

This study makes several contributions. First, the ACS measures provide new information about the effects of the disaster on a broad set of health impairments, limitations, and restrictions, as well as overall disability. Second, the use of a large sample that is representative of all adults in New Orleans before and after Katrina overcomes a major limitation of much previous research on the effects of the hurricane (De Souza Briggs, 2006; National Academy of Sciences, 2007), which has focused on select population groups and yielded results that may not be generalizable. Third, we examine demographic disparities in post-disaster health by age, race, and sex, an important topic on which research has been scarce in the past (Galea, Nandi, & Vlahov, 2005; Norris, Friedman, & Watson, 2002a, 2002b). Finally, the focus on New Orleans enhances our understanding of the disaster's effect on the largest population center in Katrina's path and a city characterized by major health disparities among its diverse population (Elliott & Pais, 2006; Sharkey, 2007).

Methods

Data and measures

We used ACS restricted data to examine the effect of Hurricane Katrina on the prevalence of impairments and disability among adults who lived in New Orleans prior to the hurricane. This secondary data analysis project was reviewed and approved by the University of Michigan institutional review board. The ACS included a large sample of pre-Katrina residents of New Orleans whose residential locations throughout the country were observed in the year after the hurricane. We reweighted this sample (results not shown) to more accurately match the pre-Katrina population of New Orleans and to overcome a concern that the post-Katrina sample may underrepresent certain segments of the population due to differential non-response, choices about dwelling type and living arrangements, and other factors. ACS restricted data included the date of interview, detailed geographic identifiers, and a larger sample, all of which were essential for conducting the analysis.

The ACS was designed to replace the long form of the decennial census. It uses a series of monthly national samples and is fielded continuously (U.S. Census Bureau, 2006). Approximately three million households are interviewed for the ACS each year. The ACS is primarily a mail survey, but with a telephone and in-person follow-up for non-respondents. The survey includes questions covering topics such as basic demographic characteristics, schooling, employment, and dwelling characteristics. The ACS questionnaire is generally completed by one household respondent, who is a household member at least 18 years of age. The ACS achieves a 98% response rate and data quality and completeness are very high (National Research Council, 2007).

The ACS disability-related outcomes include reports of: (1) blindness, deafness, or severe vision or hearing impairment; (2) a condition that substantially limits basic physical activities; (3) difficulty learning, remembering, or concentrating; (4) difficulty dressing, bathing, or getting around inside the home; (5) difficulty going outside the home alone to shop or visit a doctor's office; (6) difficulty working at a job or business; and (7) any of the preceding six health conditions.

The ACS disability questions are based on a questionnaire module designed by a federal interagency workgroup for the 2000 Decennial Census (Adler, Clark, DeMaio, Miller, & Saluter, 1999). The ACS disability measures can be mapped (see Weathers, 2005) to the World Health Organization (2001) International Classification of Functioning, Disability, and Health (ICF). The ICF is one of the most widely-used conceptual models of disability and recognizes that disability involves interactions among health conditions, individual characteristics, physical setting, and the social environment (see Jette & Badley, 2000). Key ICF concepts reflected in the ACS disability measures include sensory, physical, and mental impairments; self-care activity limitations; mobility and work participation restrictions; and disability (Weathers, 2005; World Health Organization, 2001).

The conceptualization of disability starts with the presence of an underlying health condition (i.e., a disease, injury, or disorder); this condition may result in a loss of function that is reflected by a sensory, physical, or mental impairment; and, finally, the health condition or the impairment may lead to a self-care limitation or a mobility or work restriction if the condition or impairment impinges upon the person's life situations (World Health Organization, 2001). The overall disability measure omits the underlying health condition but captures both impairments and limitations/restrictions. Often there is a direct progression from a health condition to an impairment and then to a restriction. However, this does not necessarily occur—for example, it is possible for a person to have a health condition and an impairment without having a limitation or restriction. Consequently, the encompassing disability measure is a useful concept to examine, even if there is an overlap in impairments and limitations/restrictions for some individuals.

A mapping between the disability concepts and the ACS disability questions is shown in Table 1. The ACS disability measures have been used to examine the socioeconomic gradient in disability

Table 1
Disability questions and concepts in the American community survey.

ACS question	Concept description
Does this person have any of the following long-lasting conditions:	
Blindness, deafness, or a severe vision or hearing impairment?	Sensory impairment
A condition that substantially limits one or more basic physical activities such as walking, climbing stairs, reaching, lifting, or carrying?	Physical impairment
Because of a physical, mental, or emotional condition lasting 6 months or more, does this person have any difficulty in doing any of the following activities:	
Learning, remembering, or concentrating?	Mental impairment
Dressing, bathing, or getting around inside the home?	Self-care activity limitation
Because of a physical, mental, or emotional condition lasting 6 months or more, does this person have any difficulty in doing any of the following activities:	
Going outside the home alone to shop or visit a doctor's office?	Mobility restriction
Working at a job or business?	Work participation restriction
Any of the impairments, limitations, or restrictions?	Disability

(Minkler, Fuller-Thomson, & Guralnik, 2006), race disparities in disability (Lee, 2011; Nuru-Jeter, Thorpe, & Fuller-Thomson, 2011), and trends in disability (Fuller-Thomson, Yu, Nuru-Jeter, Guralnik, & Minkler, 2009).

Statistical analysis

Our empirical strategy involved constructing two samples describing this same population: one collected during the twenty months prior to Katrina and the other collected during the first year following Katrina. To ensure the comparability of the two samples, we developed a propensity-score reweighting procedure for the post-Katrina sample. These weights ensure that the post-Katrina sample represents the same underlying population even if some groups were under-represented in the unadjusted sample.

We constructed the pre- and post-Katrina samples using information on the date of each individual's ACS interview, each individual's county of residence at that time, and each individual's county of residence one-year prior to the interview. We included individuals in the pre-Katrina sample whose interviews occurred between January 1, 2004 and August 28, 2005 and who lived in Orleans Parish at the time of the ACS interview. We included individuals in the post-Katrina sample whose interviews occurred between November 1, 2005 and August 29, 2006 and who lived in Orleans Parish one year prior to the ACS interview—regardless of the residence location at the time of the interview. This procedure ensured that the post-Katrina sample includes both evacuees and those who were able to return to New Orleans more quickly. Finally, we included only individuals who were at least 25 years old on December 31, 2005, in order to incorporate detailed information on educational attainment into the analysis. By age 25 years, most adults have completed their schooling (or have entered the highest education category); hence, this restriction allowed us to consider educational attainment as an age- and time-invariant characteristic when estimating the propensity score model.

The propensity score, $\rho(x)$, is defined as the probability that an observation with characteristics $X = x$ drawn at random from a pooled sample of both pre- and post-Katrina observations came from the post-Katrina sample: $\rho(x) \equiv P(t = \text{post-Katrina} | x_i = x)$. We obtained an estimate of the propensity scores by estimating a logistic regression of a dummy indicator that an observation came from the post-Katrina sample on a vector of demographic variables X among a pooled sample that contained both pre- and post-Katrina observations, weighting by ACS sampling weights. The explanatory variables for the propensity score model included five-year age categories, race and ethnicity indicators, sex, educational attainment categories, and place-of-birth dummies. We conducted a specification search across models with different orders of interactions among these variables in order to identify the model with the best fit. As part of this search, we estimated models with all possible one-way, two-way, three-way, and four−way interactions. We used the Akaike information criterion (AIC) to assess goodness of fit while accounting for model complexity and selected the model specification with the smallest AIC.

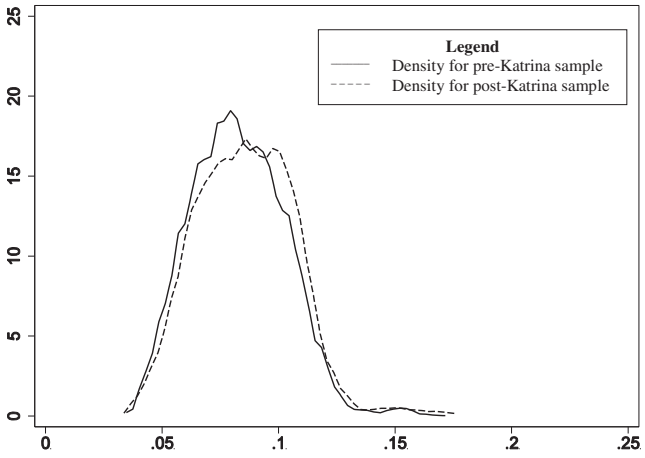
For each ACS observation i, we computed an estimated propensity score $\widehat{\rho}(x_i)$ by applying the logistic cumulative density function to the estimated regression evaluated at x_i. In all substantive analyses, we weighted each post-Katrina observation by the product of the ACS sampling weight and the estimated propensity score weight,

$$\widehat{w} = \left[\frac{1 - \widehat{\rho}(x_i)}{\widehat{\rho}(x_i)}\right]\left[\frac{\widehat{\rho}}{1 - \widehat{\rho}}\right], \quad (1)$$

where $\widehat{\rho}$ is the unconditional (on x) probability that an observation came from the post-Katrina sample. This approach ensures the comparability of the two samples under the assumption that there are no unobserved effects that influence the probability of being included in the post-Katrina sample and are correlated with outcomes of interest.

The possibility that unobserved factors could contribute to differential survey non-response after Hurricane Katrina is a concern in principle. There are, however, two main factors that are likely to make this concern a minor one. First, the ACS achieves exceedingly high response rates, leaving a very narrow scope for differential non-response to have an effect on the results. Second, the ACS sampling weights and the propensity score weights together account for a wide range of observable factors that are directly related to non-response and indirectly correlated with unobserved factors. Together, these factors are likely to reduce significantly the scope for unobserved factors to have an important effect on the study findings.

We conducted a detailed assessment of covariate balance between the pre- and post-Katrina samples. Although we found small but statistically significant differences between pre- and post-Katrina characteristics for many observed characteristics when comparing means using just the ACS weights, essentially all of these differences were rendered statistically insignificant once the propensity score weights were applied. Finally, we assessed the overlap of the propensity score's distribution in the pre-Katrina sample and post-Katrina samples. We found that the pre- and post-Katrina distributions shared common support and were bounded away from zero and one, indicating that the propensity score weights were well-behaved. Fig. 1 shows estimated propensity scores for the pre-Katrina and post-Katrina ACS samples, and provides evidence for the close, overlapping distribution of propensity scores for the two samples.



Note: The propensity score is the estimated probability that an observation came from the post-Katrina sample conditional on the model covariates. The propensity score model is estimated with observations on individuals who lived in New Orleans one year prior to the interview (regardless of where they lived at the time of the interview) and on individuals from a pre-Katrina sample of New Orleans residents from January 2004 through August 2005.

Fig. 1. Distribution of estimated propensity scores: Overlap between pre-Katrina and post-Katrina samples from the American community survey.

We estimated the prevalence of health impairments and disability before Katrina and the change in prevalence after Katrina using linear probability models of the following form:

$$Y_i = \beta_0 X_i + \beta_1 (X_i \times \text{Post}_i) + \varepsilon_i, \quad (2)$$

where Y_i is an indicator of impairment or disability, X is a vector of dummy demographic variables, Post is an indicator that an observation came from the post-Katrina sample, and ε_i is an error term. The parameter vector β_0 describes the prevalence of the outcome prior to Katrina and β_1 describes the change in the outcome's prevalence following the hurricane. To investigate the change in the outcome's prevalence for the whole population, we defined X to be a constant. We also investigated disability levels and changes for particular subgroups by defining the X appropriately. For instance, we estimated models by race by having X provide an indicator that distinguishes blacks from non-blacks. We estimated models for age, race, and sex, and, finally, for all three−way interactions. The linear probability model approximates a logit or probit regression model but has the advantage of providing a direct estimate of the pre-Katrina prevalence and the marginal effect of the hurricane (Angrist, 2001).

Our analysis focused on three independent variables: age, race, and sex. In Table 2 we present descriptive statistics for the analysis sample, which comprises of 3525 individuals from the pre-Katrina period and 2784 individuals from the post-Katrina period. Two sets of results are shown for the post-Katrina period: the results in Column 2 used the ACS weights alone while the results in Column 3 used the ACS weights and the propensity score weights. The summary statistics based on the two independent samples of New Orleans adults from before and after Katrina are remarkably close to each other, reflecting the high quality of the ACS data. A comparison of the second and third columns with each other and with the summary statistics for the pre-Katrina sample shows that applying the propensity score weights results in estimates that are closer to those for the pre-Katrina sample, although the changes are subtle. The results in Table 2 show that young adults aged 25−39 years made up approximately one-third of the sample, middle-aged adults aged 40−59 years comprised 44% of the sample, and elderly adults aged 60+ years accounted for the remaining one-quarter of observations. Blacks accounted for just over 60% of adults in New Orleans prior to Katrina and females comprised 56%.

Results

Our regression results are presented in Tables 3 and 4. Table 3 displays results for the entire adult population and for each of the independent variables on its own, while Table 4 presents results for subgroups defined by race, sex, and age. For each of the seven impairment and disability outcomes, two columns of results are shown in each table. The first column shows the pre-Katrina prevalence of the specific outcome measure while the second column shows the post-Katrina change in prevalence. Each entry also includes a robust estimate of the standard error and, for the post-Katrina change in prevalence, an indication of the statistical significance of the parameter estimate. Thus, the first entry in Table 3 shows that the pre-Katrina prevalence of sensory impairment among the adult population was 5.5% and the second entry shows that the post-Katrina change was a statistically insignificant 0.5 percentage point increase in sensory impairment. Impairment and disability rates for the pre-Katrina New Orleans adult population are generally quite similar to rates for the entire U.S. (results not shown). Formal t-tests of the equivalence between independent pairs of parameter estimates can be obtained using the information presented in the tables. The t-test statistic is the ratio of the difference in estimated parameters to the standard error of the difference which is equal to $\sqrt{(\text{SE}_1)^2 + (\text{SE}_2)^2}$. We report the results of these tests in the text when comparing findings for different demographic groups.

For the New Orleans adult population as a whole, there were statistically significant increases following Hurricane Katrina in physical impairment, mental impairment, and disability. The level of mental impairment rose by 2.7 percentage points from its pre-Katrina value of 5.8%—an increase of 50%. Physical impairment rose by 2.2 percentage points from its pre-Katrina rate of 14.1%, while the overall estimate of disability rose 4.0 percentage points from 20.6% to 24.6%.

Examining the post-Katrina change by age reveals that the increases in disability occurred exclusively among young and

Table 2
Descriptive statistics for pre-Katrina adult residents of New Orleans in 2004−2005 (Pre-Katrina) and in 2005−2006 (Post-Katrina).

Variable	2004−2005 ACS ACS weights	2005−2006 ACS	
		ACS weights	ACS and propensity score weights
Age			
25−39	30.6% (1.3%)	30.8% (1.3%)	30.3% (1.3%)
40−59	44.3% (1.3%)	45.0% (1.3%)	44.6% (1.3%)
60+	25.0% (1.1%)	24.2% (1.2%)	25.1% (1.1%)
Race			
Black	62.7% (1.5%)	61.6% (1.5%)	61.6% (1.5%)
Non-black	37.3% (1.5%)	38.4% (1.5%)	38.4% (1.5%)
Sex			
Female	55.6% (0.9%)	53.7% (1.0%)	54.9% (1.0%)
Male	44.4% (0.9%)	46.3% (1.0%)	45.1% (1.0%)
Observations	3525	2784	2784

Notes: Standard errors in parentheses. The 2004−2005 ACS estimates are based on individuals residing at the time in the city of New Orleans and are weighted using the ACS weights; the 2005−2006 ACS estimates are based on individuals throughout the U.S. who reported living in the city of New Orleans one year previously and are weighted using the ACS weights (column 2) or the product of the ACS weights and the propensity score weights (column 3).

Table 3
Pre-Katrina levels and post-Katrina changes in health impairments, limitations, and restrictions: by age, by race, and by sex.

Group	Sensory impairment		Physical impairment		Mental impairment		Self-care limitation		Mobility restriction		Work restriction		Disability	
	Pre-Katrina prevalence	Post-Katrina change	Pre-Katrina prevalence	Post-Katrina change	Pre-Katrina prevalence	Post-Katrina change	Pre-Katrina prevalence	Post-Katrina change	Pre-Katrina prevalence	Post-Katrina change	Pre-Katrina prevalence	Post-Katrina change	Pre-Katrina prevalence	Post-Katrina change
All	0.055	0.005	0.141	0.022#	0.058	0.027**	0.049	0.003	0.078	0.007	0.147	−0.003	0.206	0.040**
	[0.005]	[0.008]	[0.008]	[0.012]	[0.005]	[0.009]	[0.004]	[0.007]	[0.006]	[0.009]	[0.009]	[0.013]	[0.010]	[0.015]
Age														
25–39	0.015	0.003	0.018	0.045***	0.030	0.015	0.011	0.001	0.014	0.017#	0.033	0.031*	0.058	0.064***
	[0.004]	[0.008]	[0.004]	[0.012]	[0.007]	[0.011]	[0.003]	[0.006]	[0.004]	[0.009]	[0.007]	[0.013]	[0.009]	[0.018]
40–64	0.028	0.025**	0.122	0.022	0.041	0.032**	0.035	0.010	0.053	0.001	0.120	0.001	0.168	0.051**
	[0.004]	[0.009]	[0.010]	[0.016]	[0.005]	[0.011]	[0.005]	[0.010]	[0.007]	[0.010]	[0.010]	[0.015]	[0.012]	[0.019]
65+	0.198	−0.044	0.400	−0.017	0.150	0.034	0.152	−0.012	0.256	0.009	0.410	−0.069#	0.559	−0.033
	[0.022]	[0.030]	[0.025]	[0.036]	[0.021]	[0.031]	[0.017]	[0.024]	[0.023]	[0.034]	[0.025]	[0.037]	[0.024]	[0.037]
Race														
Black	0.054	0.013	0.163	0.022	0.067	0.025*	0.055	0.005	0.087	0.002	0.168	−0.015	0.225	0.048*
	[0.007]	[0.011]	[0.011]	[0.017]	[0.008]	[0.012]	[0.006]	[0.010]	[0.008]	[0.012]	[0.012]	[0.017]	[0.014]	[0.021]
Non-black	0.056	−0.006	0.104	0.023	0.042	0.032*	0.040	0.001	0.064	0.016	0.110	0.020	0.174	0.028
	[0.008]	[0.010]	[0.009]	[0.015]	[0.007]	[0.013]	[0.006]	[0.009]	[0.009]	[0.014]	[0.011]	[0.017]	[0.014]	[0.020]
Sex														
Male	0.048	0.024*	0.138	0.006	0.061	0.009	0.043	−0.000	0.065	0.004	0.147	−0.003	0.204	0.031
	[0.006]	[0.011]	[0.011]	[0.016]	[0.008]	[0.012]	[0.006]	[0.009]	[0.008]	[0.011]	[0.013]	[0.018]	[0.014]	[0.021]
Female	0.060	−0.009	0.144	0.035*	0.055	0.042***	0.054	0.006	0.088	0.011	0.146	−0.002	0.207	0.047**
	[0.007]	[0.010]	[0.010]	[0.016]	[0.007]	[0.012]	[0.006]	[0.010]	[0.009]	[0.013]	[0.011]	[0.015]	[0.012]	[0.018]

Note: Robust standard errors in parentheses; #$p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$.

middle-aged adults—there was no statistically significant increase in any of the disability measures among the elderly. The disability rate more than doubled among young adults, increasing by 6.4 percentage points from its pre-Katrina prevalence of 5.8%. The magnitude of the increase for middle-aged adults was similar to that for young adults, with a t-statistic for the difference of $\frac{(0.064 - 0.051)}{\sqrt{(0.018)^2 + (0.019)^2}} = 0.50$ and a p-value of 0.619, although the pre-Katrina prevalence was much higher at 16.8% ($t = 7.33$; $p < .001$). (In contrast, the disability rate was 55.9% among the elderly.) Different dimensions of impairment and restrictions contributed to the increase in disability for younger adults compared to middle-aged adults. For younger adults, there were statistically significant increases in physical impairment (an increase of 4.5 percentage points from 1.8%), mobility restrictions (up 1.7 percentage points from 1.4%), and work restrictions (up 3.1 percentage points from 3.3%), while for middle-aged adults there were increases in sensory impairment (up 2.5 percentage points from 2.8%) and mental impairment (up 3.2 percentage points from 4.1%).

There were increases in disability following Hurricane Katrina for both blacks (an increase of 4.8 percentage points) and non-blacks (2.8 percentage points), although only for blacks was the change statistically significant (and the difference in the change between blacks and non-backs was not statistically significant). However, there were no clear differences by race in changes in impairments, limitations, or restrictions following Hurricane Katrina.

Finally, differences by sex in post-Katrina changes in impairments, limitations, and restrictions show that females fared substantially worse than males—although none of the differences by sex were statistically significant at the 0.05 level. While males experienced an increase in sensory impairments in the year following the hurricane (up 2.4 percentage points from 4.8%), females had major increases in physical impairment (up 3.5 percentage points from 14.4%) and mental impairment (up 4.2 percentage points from 5.5%). The overall effect was a statistically significant increase in disability among females, which rose by 4.7 percentage points from 20.7%.

The pattern of results from the univariate analysis are reflected clearly and consistently in the multivariate analysis, shown in Table 4. In particular, young and middle-aged black women appear to have experienced by far the largest increase in disability following Hurricane Katrina of any of the age-race-sex groups that we examined. Overall disability rose by 11.5 percentage points in the year after the hurricane for young black females, a tripling of disability from the 4.6% rate in the period prior to the hurricane. Among middle-aged black females, the disability rate increase by 10.9 percentage points, up from 15.1% prior to the hurricane. For both younger and middle-aged black women, there were large, statistically significant increases in physical and mental impairment. Young black women also experienced increases in mobility and work restrictions. The increase in mental impairment for young black women was particularly striking—the prevalence was less than 1% prior to the hurricane, but increased by 6.0 percentage points in the year following Katrina.

No other age-race-sex group experienced statistically significant post-Katrina changes in disability, although there were some increases in impairment, limitations, and restrictions for certain groups. However, no consistent pattern of results emerged as it did for young and middle-aged black females. There was an increase in sensory impairment for middle-aged black males, in physical impairment for young black males, in work restrictions for young non-black males, mobility restrictions for elderly non-black males,

Table 4
Pre-Katrina levels and post-Katrina changes in health impairments, limitations, and restrictions: race-by-Sex-by-Age.

Group	Sensory impairment		Physical impairment		Mental impairment		Self-care limitation		Mobility restriction		Work restriction		Disability	
	Pre-Katrina prevalence	Post-Katrina change	Pre-Katrina prevalence	Post-Katrina change	Pre-Katrina prevalence	Post-Katrina change	Pre-Katrina prevalence	Post-Katrina change	Pre-Katrina prevalence	Post-Katrina change	Pre-Katrina revalence	Post-Katrina change	Pre-Katrina prevalence	Post-Katrina change
Black male by age														
25–39	0.011	0.024	0.015	0.056*	0.070	−0.037	0.013	−0.005	0.025	0.006	0.062	0.025	0.091	0.053
	[0.006]	[0.019]	[0.006]	[0.023]	[0.024]	[0.028]	[0.007]	[0.009]	[0.011]	[0.018]	[0.023]	[0.034]	[0.025]	[0.041]
40–64	0.034	0.066**	0.191	−0.019	0.054	0.025	0.048	0.011	0.083	−0.025	0.208	−0.027	0.255	0.023
	[0.009]	[0.022]	[0.026]	[0.036]	[0.012]	[0.023]	[0.013]	[0.022]	[0.019]	[0.023]	[0.027]	[0.038]	[0.028]	[0.042]
65+	0.169	0.004	0.433	−0.098	0.183	−0.031	0.151	−0.035	0.215	−0.030	0.407	−0.127#	0.549	−0.065
	[0.037]	[0.067]	[0.053]	[0.077]	[0.040]	[0.055]	[0.039]	[0.051]	[0.044]	[0.063]	[0.054]	[0.077]	[0.055]	[0.084]
Black female by age														
25–39	0.018	0.002	0.025	0.057*	0.009	0.060**	0.013	0.007	0.011	0.042*	0.026	0.049*	0.046	0.115***
	[0.007]	[0.013]	[0.008]	[0.026]	[0.004]	[0.019]	[0.006]	[0.013]	[0.006]	[0.018]	[0.008]	[0.021]	[0.011]	[0.032]
40–64	0.031	0.016	0.109	0.074**	0.042	0.058**	0.033	0.028#	0.043	0.026	0.099	0.025	0.151	0.109***
	[0.007]	[0.014]	[0.013]	[0.026]	[0.008]	[0.018]	[0.007]	[0.016]	[0.008]	[0.017]	[0.013]	[0.022]	[0.016]	[0.030]
65+	0.217	−0.093#	0.522	−0.017	0.193	−0.011	0.203	−0.031	0.353	−0.025	0.522	−0.163*	0.654	−0.085
	[0.046]	[0.055]	[0.044]	[0.067]	[0.046]	[0.059]	[0.033]	[0.048]	[0.047]	[0.065]	[0.044]	[0.064]	[0.039]	[0.063]
Non-black male by age														
25–39	–	–	0.013	0.034	–	–	0.005	0.001	–	–	0.011	0.036*	0.032	0.055#
			[0.008]	[0.024]			[0.005]	[0.007]			[0.006]	[0.017]	[0.016]	[0.030]
40–64	0.017	0.007	0.083	0.004	0.032	0.008	0.032	−0.020#	0.043	−0.012	0.084	−0.009	0.118	0.012
	[0.007]	[0.011]	[0.015]	[0.023]	[0.011]	[0.017]	[0.009]	[0.011]	[0.011]	[0.016]	[0.016]	[0.024]	[0.018]	[0.028]
65+	0.211	−0.049	0.254	0.027	0.118	0.023	0.076	0.039	0.094	0.132*	0.229	0.080	0.419	0.063
	[0.041]	[0.053]	[0.041]	[0.061]	[0.032]	[0.048]	[0.027]	[0.041]	[0.029]	[0.053]	[0.040]	[0.063]	[0.047]	[0.071]
Non-black female by age														
25–39	0.014	−0.014	0.013	0.016	0.043	−0.028	0.010	−0.004	–	–	0.029	−0.003	0.059	−0.013
	[0.009]	[0.009]	[0.007]	[0.017]	[0.016]	[0.018]	[0.009]	[0.010]			[0.014]	[0.017]	[0.018]	[0.025]
40–64	0.021	−0.002	0.081	−0.009	0.028	0.011	0.024	−0.002	0.035	−0.003	0.064	0.009	0.115	0.009
	[0.009]	[0.012]	[0.018]	[0.024]	[0.013]	[0.017]	[0.009]	[0.014]	[0.011]	[0.016]	[0.016]	[0.023]	[0.020]	[0.029]
65+	0.186	−0.021	0.309	0.070	0.086	0.162**	0.138	0.010	0.269	0.025	0.387	0.012	0.535	0.015
	[0.034]	[0.049]	[0.039]	[0.061]	[0.023]	[0.059]	[0.030]	[0.045]	[0.040]	[0.068]	[0.040]	[0.066]	[0.043]	[0.066]

Note: Robust standard errors in parentheses; #$p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$; cells with "–" are suppressed because the population was smaller than the Census disclosure avoidance threshold.

and mental impairments for elderly non-black females. The lack of a clear pattern for these other groups further highlights the striking nature of results for young and middle-aged black females.

An interesting comparison emerges from contrasting disability rates between black females and non-black females. Prior to Hurricane Katrina, young black females had a disability rate of 4.6%, not significantly different to that for young non-black females of 5.9%; corresponding figures for middle-aged black and non-black females were 15.1% and 11.5%, also a statistically insignificant difference. The experience of these two groups diverged sharply in the year following the hurricane. Young black females had a disability rate of 16.1%, over three-times as high as the disability rate of 4.6% for young non-black females, a difference that was statistically significant ($t = 2.51$; $p = .012$); among middle-aged females, blacks had a disability rate of 26.0% that was twice as high as that for non-blacks and statistically significantly different ($t = 2.78$; $p = .006$).

Discussion

We examined changes in health impairments, limitations, restrictions, and disability among the adult population of New Orleans in the year following Hurricane Katrina, in order to further our understanding of the broader health effects of this major disaster. This is an important topic that has been largely missing from the literature on the health effects of the hurricane, primarily due to lack of appropriate, representative data. We found a significant decline in health for the adult population from New Orleans in the year after the hurricane, with the disability rate rising from 20.6% to 24.6%. This increase in disability reflected a large rise in mental impairments and, to a lesser extent, in physical impairments. These increases were, in turn, concentrated among young and middle-aged black females.

The pattern of results we uncovered has not been clearly identified in research to date that has examined the health effects of Hurricane Katrina on adults from New Orleans. However, the findings are consistent with those from analyses that have focused on a more limited set of outcomes—particularly psychological distress and post-traumatic stress disorder. Prior studies have consistently found worse mental health among non-elderly adults, females, and blacks (Galea et al., 2007; Kessler et al., 2006; Sastry & VanLandingham, 2009). Studies that focused on women and blacks (e.g., Jones-DeWeever, 2008; Zwiebach, Rhodes, & Roemer, 2010) have argued that these women were particularly susceptible to suffering adverse effects from the disaster, for a variety of reasons. However, most of these analyses lacked representative samples with which to compare the post-Katrina experience of black women with those of other demographic groups and many also lacked pre-Katrina health measures. Our analysis, however, reveals that black women did indeed experience the most deleterious physical and mental health outcomes, as reflected through the various ACS disability-related indicators.

Our data do not include direct measures that might explain why young and middle-aged black women experienced worse health outcomes, although the existing literature does suggest a variety of possible factors—all of which build on the strong theoretical and empirical relationship that has been found to exist between higher levels of stress and adverse health outcomes. The first factor is the broad and well-documented evidence that blacks were far more likely to live in dwellings and communities that suffered the most damage from the hurricane (Logan, 2006; Sastry & VanLandingham, 2009). This not only resulted in higher rates of displacement and a lower likelihood of return in the year after the hurricane (Fussell, Sastry, & VanLandingham, 2010; Groen & Polivka, 2010; Paxson & Rouse, 2008), but also higher chances of adverse economic outcomes such as property losses and unemployment (Vigdor, 2007; Zissimopoulos & Karoly, 2010), loss of community and neighborhood ties, having friends and family members who were injured or killed in the disaster, and other associated negative outcomes. Second, displacement in the aftermath of Katrina was associated with a high rate of break-up of households (Rendall, 2011) which may have had particularly acute negative effects for women with young children. Third, children experienced sharp declines in school outcomes in the year after Katrina (Sacerdote, 2012) which, along with other child-related stressors (Lowe, Chan, & Rhodes, 2011), may have contributed to stress for their mothers. These factors, together with the greater susceptibility of women, parents, and the economically disadvantaged to adverse mental health outcomes following disasters (Galea et al., 2005), suggest the possible reasons why non-elderly black women were more likely to have experienced the worst disability-related health outcomes in the aftermath of Katrina.

One interesting contrast in the disability effects of Hurricane Katrina emerges from examining the multiple dimensions of the outcome measures—and, in particular, comparing the changes in impairments, limitations/restrictions, and overall disability between young and middle-aged black females. For the former group, the post-Katrina increase in physical and mental impairments was associated with a rise in mobility and work restrictions; however, for the latter group, the higher post-Katrina level of physical and mental impairments was associated only with a minor (and statistically insignificant) increase in mobility and work restrictions. This result suggests that the disability effects for younger black females were more consequential, because their impairments also affected their ability to function outside the home for tasks such as shopping or visiting a doctor and for work. The difference in functional ability may reflect other factors—such as middle-aged black women being more affluent, having older children who are able to help with shopping and other tasks, and having lower labor force participation rates. Nevertheless, this result points to broader deleterious effects on disability for younger black women due to Hurricane Katrina. This finding also highlights the importance of research examining the effects of disasters on health-related functioning—not just the health outcomes alone—to obtain a more complete picture of the effects of disasters on individuals and populations. Policies to mitigate the negative effects of disasters should also consider their effects on functioning which provides a measure of well-being beyond disability or health status alone.

This study has a number of strengths. Foremost among these is the use of high-quality data representative of all adults who lived in New Orleans prior to Hurricane Katrina—regardless of where in the country they resided in the year following the disaster. These data allowed us to estimate the causal effects of the disaster on impairments, limitations, restrictions, and disability in the aftermath of the hurricane. The ACS disability questions have a number of strengths: the questions remained the same over the study period and they capture important dimensions of health-related functioning.

This study also has several limitations. First, the ACS disability questions do not identify specific health conditions (e.g., diabetes, cardiovascular disease, depression, or post-traumatic stress disorder) that are the source of the disability. Second, they do not capture the extent to which social and environmental factors contribute to or ameliorate a person's disability experience. Third, with only six questions, the breadth and depth of information that is collected about disability is limited. Fourth, disability reports may be affected by mode of interview and by obtaining proxy reports rather than self-reports. Fifth, the post-Katrina sample may not adequately capture individuals who were institutionalized and may have been affected by mortality selection. Both of these last two limitations may have resulted in the analysis understating the

deleterious effects of the disaster on health outcomes for the elderly. Sixth, we lacked a rich set of measures describing the factors likely to explain why young and middle-aged black women experienced the largest negative health effects of the disaster. Finally, the study only examined outcomes in the year after Hurricane Katrina, and hence did not capture longer-term disability-related health outcomes.

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