Disaster-Related Injuries in the Period of Recovery: The Effect of Prolonged Displacement on Risk of Injury in Older Adults

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Background: Hurricane Katrina, which struck the Gulf Coast of the United States in August 2005, initially displaced over a million people from their primary place of residence. Displaced older adults subsequently faced challenges, such as new or inferior living conditions, which could increase vulnerability to serious or life-threatening injuries such as hip fracture. The aim of this study was to determine whether Katrina victims who were displaced for a prolonged period of time were more likely to experience injuries than nondisplaced victims.

Methods: We tracked injury outcomes including fractures, sprains or strains, and lacerations in a cohort of 25,019 older adults (age ≥ 65 years) enrolled in a Medicare-Advantage Plan, for 1 year after Katrina. We used medical claims to obtain injury outcomes and analyzed propensity-score adjusted predictors of injury, including displacement status at 12 months.

Results: In our sample, 7,030 (28%) older adults were displaced at 12-month post-Katrina. Displaced victims had 1.53 (95% CI: 1.10–2.13) greater odds of sustaining a hip fracture in the year after the storm and 1.24 (95% CI: 1.07–1.44) greater odds of sustaining other fractures after adjusting for other risk factors. There was no significant association between displacement status at 12 months and sprains or strains or lacerations.

Conclusions: Prolonged displacement is associated with increased risk of fracture in older adults. Emergency planners should screen temporary housing for injury hazards, and clinicians should regard displaced older adults as a vulnerable population in need of interventions such as risk communication messaging.

Key Words: Hip fracture, Hurricane Katrina, Disasters, Displacement, Older adults.

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Injury prevention efforts in disasters typically focus on the immediate impact of the event. However, evidence suggests that victims are exposed to ongoing risk. One study found that 79% of all Hurricane Andrew-related injuries occurred after (rather than during) the storm.[1] In Hurricane Katrina, a storm that struck the Gulf Coast of the United States in 2005 and initially displaced over a million people from their primary place of residence, the vast majority of injuries were reported by individuals engaged in clean-up or rebuilding activities.[2] Postdisaster injury further taxes over-burdened health care systems; after Katrina 58% of all visits to health care facilities were for treatment of injuries.[3]

Although first responders routinely establish injury surveillance systems in the aftermath of a major disaster, data collection, and reporting is often limited to 1 weeks to 5 weeks postevent.[1–4] Studies that track outcomes for longer periods consistently find that men and middle-aged individuals are at highest risk for postdisaster injury.[1,2,5] However, other potentially high risk subpopulations of interest, such as displaced victims and older adults, have been infrequently studied. Only two studies we identified explored injury rates in displaced versus nondisplaced victims during longer term recovery.[6,7] These studies reported conflicting findings, with one identifying an association between permanent relocation and injury, and the other no association.

Fractures of the extremities are one of the most common postdisaster injuries.[4] Even in normal, nondisaster conditions hip fracture can have particularly devastating effects in older adults. Fifteen percent of women and 6% of men will suffer a hip fracture in their lifetime,[8] often resulting in permanent disability, nursing home placement, or death.[9] Between 14% and 36% die within a year of sustaining a hip fracture.[10] There are numerous demographic and medical risk factors for hip fracture, including older age, female gender, white race, cognitive impairments, history of fracture, unmarried status, substance abuse, low body mass index, and low socioeconomic status.[11–15] More relevant for the relationship between displacement and hip fracture are environmental risk factors. Living in a one-family home and living in a home for more than 5 years reduce the risk of hip fracture.[15,16] Older adults who live in institutions, apartments, mobile homes, or in environments with poor lighting, loose mats or flooring, poorly maintained stairs, and clutter face increased risk.[11,17–20] Because displaced persons exposed to Hurricane Katrina were more likely to reside in unfamiliar or inferior housing, we hypothesized that they would face a greater risk of postdisaster hip fracture. We were also interested in the risk of other fractures as well as lacerations or sprains or strains.

We analyzed the pre- and poststorm medical claims data of a cohort of 25,019 older adult victims of Hurricane Katrina. We sought to determine whether victims who were

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displaced for a prolonged period of time were more likely to experience injuries than nondisplaced victims.

MATERIALS AND METHODS

Participants

Study participants included 25,019 enrollees in People's Health, the dominant of two Medicare Advantage plans that served the New Orleans metropolitan area at the time of Katrina. The final cohort consisted of noninstitutionalized older adults (age 65+) who were enrolled in the plan in July 2005 (just before Katrina), lived in a parish (county) in the New Orleans metropolitan area within the declared disaster zone and survived up to 12-month post-Katrina. The study population represented approximately 20% of all older adults (and 86% of all Medicare Advantage enrollees)[21] residing in Orleans, St. Tammany, Jefferson, and Plaquemines parishes in Louisiana at the time of the disaster.

Furthermore, more than one third of the region's Medicare beneficiaries were enrolled in an Advantage plan at the time of the storm, in contrast to the national average of 12%.[21]

In the 1-year period after Katrina, study participants were diagnosed and treated for numerous medical conditions other than injury including hypertension (70.3%), diabetes (23.4%), ischemic heart disease or acute myocardial infarction (23.3%), congestive heart failure (10.7%), and anxiety or depression (10.6%).

Data Sources

Medical claims and administrative data were the primary data sources. These data provided information on demographic characteristics, self-reported addresses or location, a measure of morbidity or illness expressed using the Johns Hopkins ACG Case Mix System,[22] and individual clusters of diagnoses. Additional data sources used to assign mean flood depth and damage categories to individuals' pre-Katrina locations included Rand/GCR and Associates[23] and Hurricane Katrina Damage September 10, 2005 (Federal Emergency Management Agency [FEMA], 2005) datasets.[24]

With administrative data files, we identified the self-reported, pre-Katrina (August 2005) and post-Katrina (August 2006) location of each enrollee. ArcGIS 9.2 (Environmental Systems Research Institute, 2007) software was used to geocode the addresses, providing a set of longitude and latitude coordinates. StreetMap 2000 (Environmental Systems Research Institute 2000) was used as the base map.

After data cleaning, 90% of 41,781 street addresses geocoded with a score of 80% or higher. (A high score indicates an accurate match between the enrollee address and a corresponding address in the StreetMap 2000 file.) Post office boxes, which represented 6% of the total addresses, could not be geocoded but remained in the database for use in determining displacement status post-Katrina. (For example, if the same post office box was listed as both the pre- and post-Katrina address, we made the assumption that the enrollee was not displaced.) We geocoded the remaining, complete street addresses that matched with a score of less than 80% (9% of the total street addresses) to the zip code rather than to the house-level. Thus, no address records were excluded from the analysis. With ArcGIS, we generated maps to depict the geographic distribution of enrollees and exported damage level and flood depth data at the household-level for use in statistical analyses.

Outcome and Covariate Measures

Most persons in the New Orleans metropolitan area suffered at least temporary displacement as a result of Hurricane Katrina. However, we were interested in the effects of more prolonged displacement. Therefore, we defined displaced (yes or no) individuals as those with a documented address change at 1 year (i.e., those individuals whose pre-Katrina address did not match their address at 12-month post-Katrina).

We explored several injury outcomes of interest. Injury types included sprain or strains, hip fractures, other (nonhip) fractures, and lacerations that occurred in the year after the storm (September 2005–August 2006). The prevalence of these selected injuries was based on markers—expanded diagnostic clusters (EDCs)—representing specific diseases or conditions. EDCs group diagnostic codes into clinically meaningful clusters that describe the same or related conditions. EDCs are included in the suite of tools in the Johns Hopkins ACG Case Mix System.[22]

Covariates that were included in the injury models included socio-demographic characteristics, hurricane damage, and displacement variables. African-American race, female gender, age, Medicaid dual-eligibility (a proxy for low-income status), residence within a damaged area, and pre-Katrina morbidity burden were included. We used the ACG-concurrent risk score to quantify overall morbidity burden. This score represents a proxy measure of an individual's health during the current year with the use of medical claims and demographic data. The ACG system has been validated as a risk adjustment method in older populations and used for numerous applications including disease management assessments, provider profiling, and quality measurement.[25,26] To analyze whether individuals had property damage, we determined if the street address of origin fell within FEMA-designated damage areas. Damaged zones included those that were flooded, experienced wind damage, or both. Flood depth data were available for Orleans parish residents (36% of the total cohort). We identified the mean flood depth within the census block on August 31, 2005, 2 days after the storm, and linked this value to each individual's record.

Statistical Analysis

We compared the baseline characteristics of the victims who experienced prolonged (1 year) displacement and those who did not by using *t*-tests for continuous variables and χ^2 tests for dichotomous variables. To adjust for significant baseline differences between groups, we used propensity scores methods. Propensity score analysis attempts to compare outcomes across exposed (e.g., displaced) and nonexposed (e.g., nondisplaced) groups who have a similar distribution of measured covariates and, in this way, approximates a quasi-experiment with randomization rather than an observational study. The covariate balance achieved through propensity score methods allows us to attribute outcomes to the effect of

exposure rather than differences in the distribution of covariates across groups.[27]

We first assigned a propensity score for each individual, reflecting the conditional probability of being exposed (displaced) given a set of covariates. To generate the propensity score, we ran a logistic regression model, with individual characteristics as independent variables and displacement status as the outcome. Covariates included in this nonparsimonious model included age (continuous), female gender (yes or no), pre-Katrina risk status (high or med-low), Medicaid dual-eligibility (yes or no), African-American race (yes or no), residence in damaged area (yes or no), and 15 interaction terms that reflected all possible combinations of these variables. We subsequently performed subclassification, ranking individuals by their propensity score and then creating five subclasses (quintiles) including both displaced and nondisplaced individuals with similar values on their propensity score.[28]

After calculating propensity scores and quintiles, we assessed covariate balance. We ran logistic regression models predicting displacement status, using each covariate entered into the original propensity score model as the independent variable and adjusting for propensity quintile. We verified covariate balance in all variables except African-American race; thus, African-American race was included as a covariate in all outcome models. To validate our propensity score adjustment, we checked for adequate overlap in propensity scores across groups.

For each dichotomous injury outcome, we constructed separate logistic regression models. An individual was defined as injured if he or she sustained a particular kind of injury at any time in the post-Katrina year. To compare propensity score methods with conventional regression methods, we created models on each outcome both with and without adjustment for propensity quintile.

Covariates included in the fracture models (both hip and nonhip) included African-American race, history of fracture in the proceeding year, and propensity quintile. Covariates included in the sprains or strains and laceration models included African-American race and propensity quintile. STATA statistical software version 9.0 (College Station, TX) was used to analyze the data.

RESULTS

Of the 30,412 members of the Medicare Advantage plan enrolled in July 2005, 25,019 met inclusion criteria, remaining alive, noninstitutionalized, and enrolled 12-month post-Katrina. In the year following the storm, 1,314 of the 30,412 enrollees died (4.6%). Before the storm, study participants resided in four parishes in the New Orleans metropolitan area (Fig. 1 and Table 1). Twelve-month post-Katrina, 7,030 (28%) were displaced. Storm victims resided in 45 different states, with the highest concentrations of displaced people in Louisiana and Texas. Although 28% of the cohort was displaced 12-month post-Katrina, 91% continued to reside in Louisiana.

Victims who faced prolonged displacement differed from nondisplaced victims with respect to all observed characteristics measured at baseline. Displaced victims were significantly more likely to be African-American, low-income, older, less healthy, female, and from a FEMA-designated damaged area (Table 1). To account for baseline differences, we adjusted for propensity quintile in the various regression models. Such adjustment achieved covariate balance between displaced and nondisplaced groups (i.e., after adjustment, socio-demographic characteristics—with the exception of African-American race—no longer predicted displacement status at 12 months) (Table 2).

In the 12 months after the storm, the cohort (n = 25,019) experienced 186 (0.74%) hip fractures, 1026 nonhip or other fractures (4.1%), 1,678 (6.7%) sprains and strains, and 980 (3.9%) lacerations. Limiting the sample to those individuals who were continuously enrolled a year before and a year after Katrina (n = 20,543), we found that the prevalence of all injury types increased from the pre-Katrina to the post-Katrina year. Hip fracture prevalence increased from 0.65% to 0.81%, nonhip or other fractures from 3.5% to 4.2%, sprains or strains from 6.3% to 6.6%, and lacerations from 2.9% to 4.1%.

Standard logistic regression models and propensity-quintile adjusted models yielded similar results with respect to injury outcomes. In the standard logistic regression models, we were able to assess the association of individual covariates and injury outcomes. Displacement at 12 months (OR: 1.43, 95% CI: 1.03–2.00), female gender (OR: 2.06, 95% CI: 1.45–2.93), increasing age (OR: 1.08, 95% CI: 1.06–1.11), high risk status or morbidity (OR: 1.84, 95% CI: 1.35–2.51) history of hip fracture (OR: 12.87, 95% CI: 7.82–21.20), and non-African America race (OR: 2.87, 95% CI: 1.86–4.43) predicted hip fracture in the year after Katrina. Through the propensity adjusted analysis, we found that displaced victims had 1.53 (95% CI: 1.10–2.13) greater odds of sustaining a hip fracture in the year after the storm and 1.24 (95% CI: 1.07–1.44) greater odds of sustaining a nonhip or other fracture. Displacement status was not significantly associated with sprains or strains and lacerations (Table 3).

DISCUSSION

Although previous disaster research has often focused on injuries sustained during the event itself or in the immediate aftermath, our study explored disaster-related injuries sustained by displaced and nondisplaced victims during the longer term recovery phase. Our results indicate that persons who faced prolonged displacement were at greater risk of sustaining fractures in the year after Hurricane Katrina. These findings support the hypothesis that postdisaster relocation, which often results in new or inferior living conditions, can adversely impact older adults. For example, displaced older adults may move from a private family home to a mobile home or apartment, thus increasing their hip fracture risk.[19] Furthermore, displaced older adults may be without important personal health aids, such as glasses or walkers, and they may face home hazards that contribute to falls (e.g., lack of railings or grab bars). However, we were not able to directly measure these risk factors likely related to displacement.

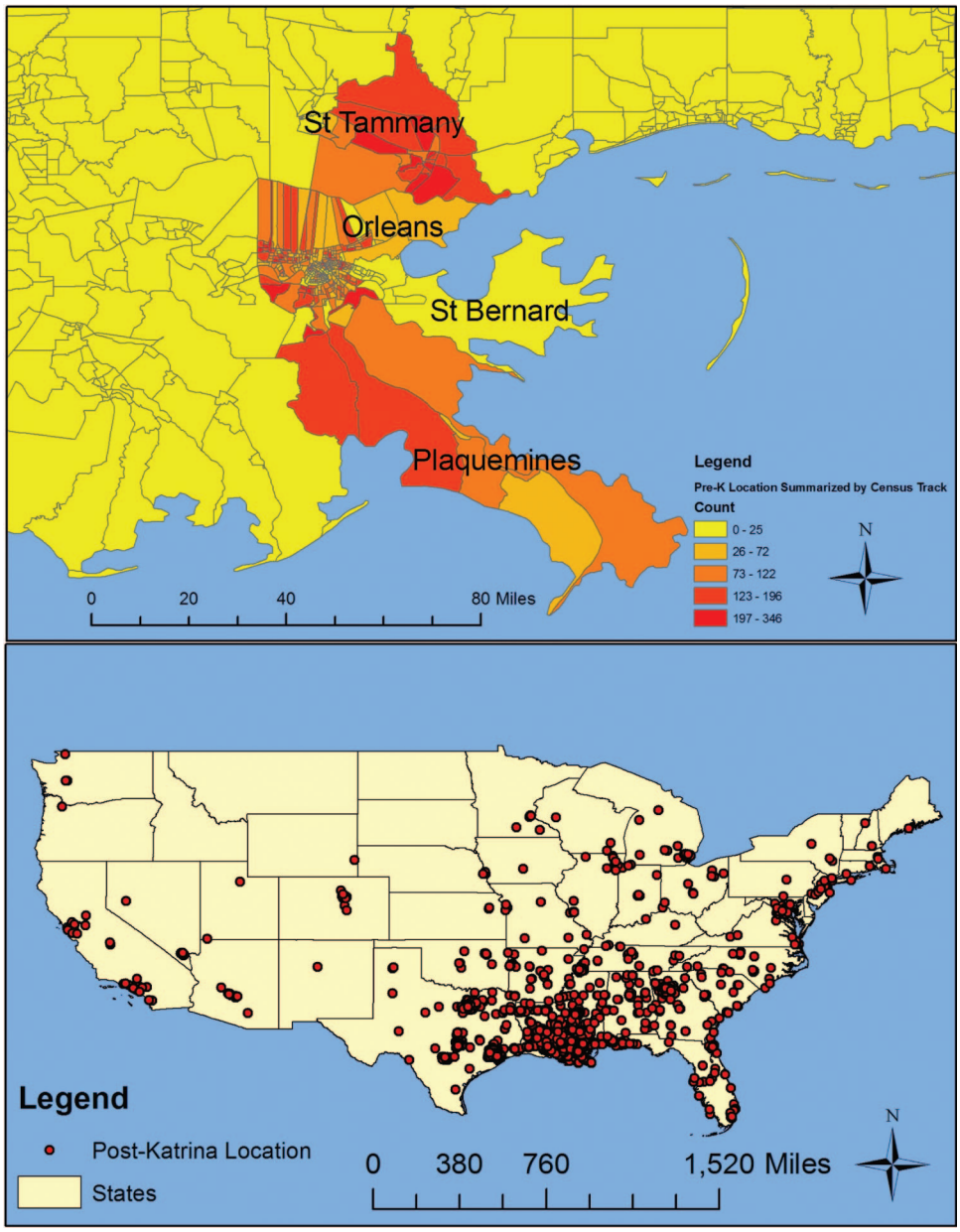

Figure 1. Pre-Katrina and 12-month Post-Katrina location of study population.

We also found no association between sprains or strains or lacerations and displacement status. This may be because, although the homes of displaced older adults are unfamiliar and often inferior to their prior residence, remaining in New Orleans posed its own unique injury risks. Post-Katrina New Orleans was characterized by unsafe roads, nonfunctional traffic lights, structural damage to buildings, debris, lack of law enforcement, and crime. Because the vast majority of hip fractures occur in the home,[18] displaced older adults are adversely impacted by exposure to new accommodations. However, because lacerations and sprains and strains are often associated with clean-up activities engaged in by nondisplaced victims,[1,2] it follows that we would observe either no association or a negative association of these outcomes with displacement status.

It is important to note that the association we identify between displacement status and fracture risk is likely to be magnified in the context of other disasters. Rarely does a metropolitan area experience an emergency on the scale of Katrina. In situations where the home city is less devastated (and thus safer), displaced individuals are likely to face even greater injury risk compared with nondisplaced individuals.

Predictors of hip fracture in our study (e.g., female gender) were consistent with the wider literature.[9,11–13] This was the case even though we created a slightly healthier cohort by excluding individuals who died in the post-Katrina

TABLE 1. Characteristics of Study Population (Displaced 12-Month Post-Katrina vs. Nondisplaced)

Characteristic	Total Number (%) (n = 25,019)	Displaced at 12 Months (n = 7,030)	Nondisplaced at 12 Months (n = 17,989)
Gender			
Female	14,458 (58)	4,349 (62)	10,109 (56)*
Age (mean, SD)	74.0 (6.6)	74.4 (6.8)	73.8 (6.5)*
African-American race	8,285 (33)	3791 (54)	4,494 (25)*
Medicaid eligible (low income) (yes)	2,848 (11)	1129 (16)	1,719 (10)*
Highest risk/morbidity category	8,587 (34)	2,612 (37)	5,975 (33)*
Parish of origin			
Jefferson Parish	11,702 (47)	1,304 (19)	10,398 (58)*
Orleans Parish	9,066 (36)	4,906 (70)	4,160 (23)*
St. Tammany	3,413 (14)	593 (8)	2,820 (16)*
Plaquemines	757 (3)	196 (3)	561 (3)
Residence in damaged area (yes)	13,219 (53)	5,479 (78)	7,740 (43)*
Flood depth in census block (mean, SD)†	4.0 (3.5)	5.4 (3.2)	2.5 (3.0)*
Injury counts in post-Katrina year			
Hip fracture	186 (0.74)	63 (0.90)	123 (0.68)
Other fractures	1,026 (4.1)	304 (4.3)	722 (4.0)
Sprains/strains	1,678 (6.7)	256 (3.6)	724 (4.0)
Lacerations	980 (3.9)	458 (6.5)	1,220 (6.8)

* Statistically significant difference ($p < 0.05$) comparing displaced and nondisplaced.
† Flood depth data available only for residents of Orleans Parish.

TABLE 2. Baseline Characteristics for Displaced and Nondisplaced Victims Before and After Adjustment for Propensity Score

	OR for Displacement Status at 12-Month Post-Katrina (95% CI)	
Covariate	Unadjusted	Adjusted for Propensity Score Quintile
Female gender	1.26 (1.19–1.34)*	1.06 (1.00–1.13)
Age	1.01 (1.01–1.02)*	1.00 (0.99–1.00)
African-American race	3.51 (3.32–3.72)*	1.25 (1.14–1.38)*
Medicaid dual-eligible	1.81 (1.67–1.96)*	1.07 (0.98–1.17)
Highest risk/morbidity category†	1.19 (1.12–1.26)*	1.04 (0.98–1.11)
Residence in damaged area	4.68 (4.39–4.98)*	1.14 (0.99–1.32)

* Statistically significant difference ($p < 0.05$).
† Based on concurrent risk score categorized by tertile.

TABLE 3. Injury Outcomes Comparing Displaced and Nondisplaced Victims in at 12-Month Post-Katrina: Results of Logistic Regression Analyses

Outcome	Nonpropensity Model* OR (95% CI)	Propensity Adjusted Model† OR (95% CI)
Hip fracture	1.43 (1.03–2.00)‡	1.53 (1.10–2.13)‡
Other fractures (excluding hip)	1.22 (1.05–1.42)‡	1.24 (1.07–1.44)‡
Sprains/strains	1.05 (0.93–1.19)	1.06 (0.94–1.20)
Lacerations	1.04 (0.89–1.21)	1.05 (0.90–1.23)

* Adjustment for displacement status at 12-month post-Katrina, African-American race, female gender, age, residence in damaged area, pre-Katrina risk status, medicaid dual-eligibility, and history of fracture (fracture models only).
† Adjustment for displacement status at 12-month post-Katrina, African-American race, propensity quintile, and history of fracture (fracture models only).
‡ Statistically significant ($p < 0.05$).

year or were institutionalized. As a result, the study population had fewer individuals in the 85+ category (7 vs. 11%) and fewer low-income older adults (11 vs. 15%) than the state of Louisiana generally. Also, our study population had more non-white older adults (35%) than Louisiana (26%), reflecting the greater proportion of minorities in New Orleans than across the state.[29] All these differences contribute to a lower hip fracture risk in the study cohort compared with the general population of older adults in Louisiana. However, because our sample size was so large, representing a substantial fraction of all older adults (from all socio-economic and racial backgrounds) in the region at the time of the storm, and we controlled for group differences within the cohort, we feel that our results are generalizable to older adults affected by Katrina. In addition, older adults are much more likely to be insured and, thus, to have access to care in the long-term after a disaster and in the event of their displacement. In fact, because Medicare coverage is nearly universal, only 1.1% of older adults are uninsured.[30] Also, Medicare beneficiaries are significantly less likely to report access challenges (in non-disaster settings) than those with private insurance or no insurance.[30,31] Even if Medicare advantage plans are likely to attract a healthier cohort than fee-for-service plans,[32] this would introduce a bias toward to the null hypothesis. All these factors are likely to enhance generalizability and reduce the influence of any selection bias in our sample.

Our study has several limitations. First, we used self-reported addresses from enrollment records to determine displacement status. Second, although we controlled for history of fracture in all fracture models, we only could identify

those with a fracture in the year proceeding Katrina. Additional years of outcome data would have provided important information on this established risk factor. Third, while propensity score methods have numerous advantages, like standard logistic regression they do not control for unobserved confounders. Fourth, there are certain limitations inherent to the use of claims data. For example, claims measure utilization rather than true population morbidity; if a patient does not seek care for a particular condition, (which is highly unlikely in the case of hip or other serious fracture) his or her illness will not be reflected in claims data.

Furthermore, we excluded all those who died in the post-Katrina year because we needed sufficient exposure to displacement to test its relationship to injury outcomes. Of the 30,412 enrolled in July 2005, 43 of 272 (16%) individuals died after a hip fracture in the post-Katrina year. (This proportion is consistent with lower-end estimates in the literature.)[10] Although not unsubstantial, we felt that this proportion was low enough to allow us to proceed with the analysis as described. By removing the people who may have died as a direct result of their hip fracture, we in effect excluded the most severe cases. In excluding both those who died and those who were institutionalized, we created a healthier cohort.

The logic behind excluding the institutionalized had to do with our concern about the issue of reverse causation. In this study, we attempt to show that displacement increases the risk of fracture, not that fracture increases the risk of displacement (i.e., after a fracture, an older adult will move to an institution because of impaired mobility and loss of function). To deal with this issue, we removed all individuals who were institutionalized. The literature suggests that in the year after hip fracture, 20% to 30% of older adults enter an institution.[33] By excluding these people, we again selected less severe injuries but we also reduced concerns about the role of reverse causation in reported associations. To test if the exclusion of these persons impacted results, we ran models with and without the institutionalized individuals and found that results were very similar.

A final concern relates to the possible misclassification of exposure. In this study, we have made the assumption that the individuals classified as displaced at 12 months were in fact first displaced at time zero (when Katrina made landfall) and remained displaced. We, therefore, can assume that fractures in the displaced group followed displacement, and fractures in the nondisplaced group did not occur during a temporary displacement. This is a reasonable assumption. Because such a small percentage of residents remained in New Orleans during the storm, Katrina was such an enormous displacement event, and many of the people who could return did so within days to weeks, we feel it is reasonable to date residential domicile changes to the time of storm.

One major strength of this study is the use of predisaster medical care utilization and health-status data, which is rare in the context of disaster research.[6] The study also benefits from large sample size, complete uninterrupted claims data, unrestricted access to healthcare for displaced persons (even out-of-network), and use of propensity score methods. It is one of the few studies to track longer term postdisaster injury outcomes and to compare displaced and nondisplaced victims.

On the basis of our results, we offer the following policy recommendations. After an evacuation—which is necessary to remove populations from immediate harm—emergency responders and decision-makers should weigh the risks of prolonged displacement on health (e.g., mental health and injury risk) against the risks and costs of return. Also, responders should provide housing for older adults that are screened for environmental hazards. At the time of this writing, FEMA was investigating the link between unsafe formaldehyde levels in trailers deployed in the wake of the 2005 hurricane season and respiratory problems in residents.[34] Living in trailers and mobile homes may also increase older adults' risk of fracture; thus, their widespread, (and in the case of Katrina) semipermanent use should be reconsidered. Finally, clinicians should regard displaced older adults as a uniquely vulnerable group and target them for injury prevention interventions. For example, risk communication tools such as checklists can be provided to displaced residents to help them assess personal and environmental risks of injury and take preventive action. If possible, residences of displaced older adults should also be screened for fall or other injury hazards. Unlike their primary residences, these new residences may never have been checked for such hazards. In relocating individuals to "safe" environments outside of the path of disaster, it is important that we avoid unnecessarily exposing older adults to risk just as we attempt to shield them from it.

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