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## Health status and health care utilization following collective trauma: A 3-year national study of the 9/11 terrorist attacks in the United States

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### ABSTRACT

The September 11, 2001 terrorist attacks (9/11) presented a unique opportunity to assess the physical health impact of collective stress in the United States. This study prospectively examined rates of physical ailments and predictors of health care utilization in a U.S. nationally representative sample over three years following the attacks. A sample of adults ( $N = 2592$ ) completed a survey before 9/11/01 that assessed MD-diagnosed physical and mental health ailments. Follow-up surveys were administered at one ( $N = 1923$ ), two ( $N = 1576$ ), and three ( $N = 1950$ ) years post-9/11 to assess MD-diagnosed physical health ailments (e.g., cardiovascular, endocrine) and health care utilization. Reports of physical ailments increased 18% over three years following 9/11. 9/11-related exposure, lifetime and post-9/11 stress, MD-diagnosed depression/anxiety, smoking status, age, and female gender predicted increased incidence of post-9/11 ailments, after controlling for pre-9/11 health. After adjusting for covariates (demographics, somatization, smoking status, pre-9/11 mental and physical health, lifetime and post-9/11 stress, and degree of 9/11-related exposure), increases in MD-diagnosed cardiovascular, endocrine, gastrointestinal, and hematology-oncology ailments predicted greater utilization of health care services over two years. After the collective stress of 9/11, rates of physical ailments increased and predicted greater health care utilization in a U.S. national sample.

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In the wake of the September 11th terrorist attacks (9/11), several studies documented short- and long-term mental health consequences in the directly impacted communities of New York City and Washington, DC (Galea et al., 2002; Neria, Gross, Marshall, & Susser, 2006; Schlenger et al., 2002). Physical health outcomes received substantially less attention, although some research found that survivors and rescue workers in New York reported many physician-diagnosed physical health problems both immediately (Feng, Lenihan, Johnson, & Reddy, 2006; Lampert, Baron, McPherson, & Lee, 2002; Steinberg et al., 2004) and as long as 5 years after 9/11 (Brackbill et al., 2006; Wheeler et al., 2007). Indeed, a growing body of research suggests extremely stressful events may trigger biological processes that increase an individual's risk of developing various health ailments (e.g., gastrointestinal, musculoskeletal, neurological; McEwen, 1998; Pizarro, Silver, & Prause, 2006; Schnurr & Green, 2004).

The 9/11 attacks were more than an isolated, individual trauma experienced by people in New York and Washington, however. The attacks were *both* a directly-experienced, individual trauma for a small proportion of Americans as well as a collective cultural upheaval for the American population as a whole (cf. Conejero & Etxebarria, 2007; Wayment, 2004). As such, their impact on mental health was seen around the country, outside the directly affected communities (Schlenger et al., 2002; Schuster et al., 2001; Silver, Holman, McIntosh, Poulin, & Gil-Rivas, 2002; Silver et al., 2006). In addition, stress responses among indirectly exposed individuals mirrored the psychological responses typically exhibited by individuals who are directly exposed to a traumatic event (Suvak, Maguen, Litz, Silver, & Holman, 2008). Elsewhere we have reported that acute stress response to the attacks in a national sample predicted an increase in reports of physician-diagnosed cardiovascular ailments over 3-years following 9/11 (Holman et al., 2008). These findings suggest that collective stress may influence more than just mental health; physical health may also suffer following these highly stressful experiences (see also Shedd et al., 2004). The present research was designed to test whether

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a collective stress such as 9/11 might have had a broader impact on physical health and health care utilization beyond directly exposed survivors.

### Linking psychological stress and physical health

There are several theories that may help explain how events like the 9/11 attacks might lead to physical ailments. Early physiologic stress responses (e.g., increased heart rate) have been linked to the development of psychological ailments (e.g., Posttraumatic Stress Disorder, PTSD; Ozer, Best, Lipsey, & Weiss, 2003), which have been associated with a variety of medical ailments (Schnurr & Green, 2004) and increased utilization of health care services (Boscarino, 2004; Fagan, Galea, Ahern, Bonner, & Vlahov, 2003). However, stress-related physiologic arousal may also produce unexplained physical symptoms that lead people to seek care from health professionals (Barsky, Orav, & Bates, 2005).

Moreover, with growing evidence identifying various biological pathways by which stress may influence disease states (e.g., Epel et al., 2004; McEwen, 1998; Miller, Cohen, & Ritchey, 2002), development of a mental illness is not necessary for the development of stress-related illness, or for increases in health care utilization that may result from these illnesses. Extreme stress triggers a neurohormonal cascade of events that supports coping in the short run, but threatens health if it does not abate after the event has passed. If these stress-related physiologic responses persist over time, it is very likely that they will be detrimental for long-term physical health (McEwen, 1998, 2008). In addition, many illnesses linked to stress-related processes are chronic in nature (e.g., McEwen, 1998), and as such, will likely impact health care utilization over a protracted period of time.

Large-scale collective events like 9/11 often set in motion a series of events, such as personal loss, economic hardship, and fears about the future (Holman et al., 2008), that may prolong and exacerbate the stress response for many people. Under these circumstances, “allostatic load” on the body increases, placing physical health at risk (McEwen, 1998, 2008). For example, persistent exposure to cortisol and other stress hormones can negatively affect bone density, increase blood pressure, promote atherosclerotic changes in arteries, and increase the risk of myocardial infarction (Brown, Varghese, & McEwen, 2004). Musculoskeletal ailments have also been associated with another form of allostatic load—HPA axis hyporesponsiveness—wherein low cortisol responses to stress allow increased secretion of inflammatory cytokines that promote autoimmune and other inflammatory diseases, many of which affect the musculoskeletal system (Boscarino, 2004; McEwen, 1998). Although a growing body of animal and human studies provides evidence consistent with the allostatic load theory (Lupien, McEwen, Gunnar, & Heim, 2009), alternative models have also been proposed (e.g., Romero, Dickens, & Cyr, 2009), in part due to the difficulty in measuring allostatic load directly (see Smith, Maloney, Falkenberg, Dimulescu, & Rajeevan, 2009). Despite theoretical differences regarding the specific mechanisms by which stress influences disease, the stress-disease relationship is widely accepted.

### The present study

To date, most research addressing the health impact of stressful life events has not included pre-event measures of mental or physical health, and few studies have been longitudinal. We sought to address these limitations and explore prospectively how collective stress might be related to physical health status and health care utilization in a national sample of American adults following the 9/11 attacks. Moreover, as allostatic load affects all

bodily systems, we sought to extend the link between collective stress and health beyond simply cardiovascular ailments (cf. Holman et al., 2008; Shedd et al., 2004). Based on prior theory and research that has linked extreme stress to physical health ailments and utilization (e.g., Boscarino, 2004; Schnurr & Green, 2004), we hypothesized that: (a) overall rates of physical ailments would increase from before to after the 9/11 attacks, (b) higher levels of 9/11-related exposure would predict increases in physical health problems, and (c) changes in physical ailments following 9/11 would be associated with health care utilization in the years following the attacks. Finally, we examined whether specific categories of physical ailments would be associated with higher utilization.

### Method

#### Overview

Starting in September, 2001, our research team conducted a longitudinal study of mental and physical health following the 9/11 attacks among a national probability sample of the U.S. population (Silver et al., 2006), in collaboration with Knowledge Networks, Inc. (KN), a Web-based survey research company. KN recruits, maintains, and conducts surveys with a nationally representative Web-enabled panel using anonymous Web-based methodology.

The KN panel was developed using traditional probability methods for creating national survey samples and recruited using stratified random-digit-dial (RDD) telephone sampling. RDD provides a known non-zero probability of selection for every household having a telephone. To ensure representation of population segments that would not otherwise have Internet access, KN provides non-Web-enabled panel households with Internet connections and appliances that use televisions as monitors (Web TV). Panel members participate in surveys 3–4 times monthly in exchange for free Internet access or other compensation (e.g., bonus points used to obtain merchandise) if the household is already Web-enabled. The KN panel closely tracks the distribution of census counts for the U.S. population on age, race, Hispanic ethnicity, education, income, geographical region, and employment status (Dennis & Krotki, 2001). To correct for possible non-response bias from panel recruitment and attrition, representative samples are selected for panel surveys using post-stratification weights that weight panel distributions to match benchmarks from the most recent government statistics for gender, age, race, ethnicity, education, and geographic region. Distributions for panel samples resemble, within sampling error, U.S. population distributions for key demographic variables.

Panel members are notified in password-protected e-mail accounts that an assigned survey is available. Surveys are confidential, self-administered and accessible any time for a designated period; participants can complete a survey only once. Members may leave the panel at any time, and receipt of the Web TV and Internet access is not contingent upon completion of any particular survey. Comparison of KN panelists' demographic, attitudinal, and behavioral responses to newly recruited RDD samples strongly suggests they do not respond as “professional” respondents (Krosnick & Chang, 2001).

KN provided demographic data for all respondents and updated these data annually. Physical health and health care utilization were assessed prior to 9/11/01; physical ailments and health care utilization were assessed annually following 9/11/01. Specifically, between October 10 and December 6, 2002, 1923 of 2281 available respondents completed the first post-9/11 health survey online (84% of those fielded; 74% of the 2592 respondents who completed

the pre-9/11 health survey). Between October 10, 2003 and March 31, 2004, 1576 of 2123 available respondents completed the second post-9/11 health survey (1491 online, 85 by mail; 74% of those fielded; 61% of respondents who completed the pre-9/11 health survey). Between September 12 and November 2, 2004, 1950 of 2471 available respondents completed the third post-9/11 health survey (1296 online, 654 by mail; 79% of those fielded; 75% of respondents who had completed the pre-9/11 health survey). Respondents who had left the KN panel were allowed to complete all surveys online or by mail. Additional waves of data were collected on subsamples of these respondents (see Silver et al., 2006); as these waves provide restricted sample sizes and are not relevant for current analyses, they are not discussed further. The Institutional Review Board of the University of California, Irvine approved the design and procedures.

## Measures

### Pre-9/11 health survey

Between June 2000 and September 9, 2001, KN administered a health survey, modeled after the Centers for Disease Control's (CDC) National Health Interview Survey (NHIS; USDHHS, 2000), to its panel. Respondents reported whether a physician had ever diagnosed them with 35 ailments (e.g., diabetes, heart problems, depression). KN benchmarked this health survey data against the annual NHIS conducted by the CDC's National Center for Health Statistics. When estimates from the 2000 NHIS were compared with 25,000 surveys from the KN database on various health measures, the average difference was less than 1.5% for self-reported smoking, heart problems, cancer, diabetes, hypertension, ulcer, migraine, and stroke, supporting the validity of these data (Baker, Bundorf, Singer, & Wagner, 2003; Dennis, 2003). Items from this survey provided the baseline assessments for our respondents ( $N = 2592$ ). A physician used the International Classification of Diseases Version 9 (ICD-9) standards (World Health Organization, 1999) to classify the 35 Health Survey ailments into ICD-9 disease system categories and several indices were created from these data: (a) total count of the number of physician-diagnosed physical health ailments, (b) a count of mental health ailments (none, anxiety or depression, both) created from questions about physician-diagnosed Anxiety Disorders (Obsessive Compulsive Disorder, Generalized Anxiety Disorder) and Depression, and (c) variables representing the number of ailments identified within each of nine separate ICD-9-based categories of ailments (i.e., musculoskeletal, cardiovascular, endocrine, respiratory, gastrointestinal, genitourinary, neurological, infectious, and hematology-oncology ailments). All indices represented counts of ailments diagnosed by a physician before 9/11/01.

Health care utilization was assessed using a series of questions addressing the number of times respondents visited a doctor in the previous year for each of the physical health ailments reported. Utilization items were scored on an 11-point scale ranging from 0 "I don't go to the doctor for this problem anymore" to 10 "more than twice a week." An index of overall health care utilization over the prior year was created from these items by identifying the greatest frequency of physician visits across all physical health ailments for each respondent. This index represented each respondent's frequency of physician visits for whichever ailment most prompted use of medical services.

### Post-9/11 health surveys

Post-9/11 follow-up surveys comparable to the pre-9/11 health survey were administered annually for three years to all available respondents who had completed the pre-9/11 health survey. The follow-up health surveys again assessed physician-diagnosed

physical and mental health ailments and health care utilization. Each health survey also included questions about respondents' smoking status, as well as height and weight that were used to calculate respondents' body mass index (BMI). Due to space limitations, health care utilization was assessed only at the 1 and 2-year time points.

Variables identical to baseline pre-9/11 health indices were created for each follow-up year: (a) total number of MD-diagnosed physical ailments, (b) total number of mental health ailments, and (c) number of ailments reported within each of the nine ICD-9 categories of disease as reported one-, two-, and three years post attacks. The pre-9/11, 1-year, 2-year, and 3-year post-9/11 health surveys were missing physician-diagnosed ailments for approximately 8–9%, 6–7%, <1%, <1% of respondents, respectively. As the missing-at-random tests for these data were non-significant ( $p > .10$ ), missing data were imputed within age groups using the expectation maximization (EM) method for pre- and 1-year post-9/11 health data (Little & Rubin, 1987).

### Additional post-9/11 assessments

A second set of follow-up surveys assessed exposure to the 9/11 attacks, exposure to stressful life events (SLE) in general, and post-9/11 somatic symptoms. These surveys were also administered annually for three years to all available respondents who had completed the pre-9/11 health survey (see Silver et al., 2006).

Exposure to the attacks was operationalized as degree of exposure to, and loss from, the attacks using items modified from prior research on disaster exposure (Holman & Silver, 1998). Individuals were categorized into one of three levels of exposure: *direct exposure*—in the World Trade Center (WTC) or Pentagon, seeing or hearing the attacks in person, or having a close relationship with someone in the targeted buildings or airplanes; *live media exposure*—watching the attacks live on television; and *no live exposure*—seeing or learning of the attacks only after they had occurred.

Lifetime exposure to stress was assessed by asking participants whether they had ever experienced each of 37 negative events (e.g., natural disaster, child abuse) and the age(s) at which they occurred. This measure was modified from the Diagnostic Interview Schedule (DIS) section on trauma (Robins, Helzer, Croughan, & Ratcliff, 1981), expanded using open-ended coding of lifetime stress reported by a primary care sample (Holman, Silver, & Waitzkin, 2000), and has provided rates of specific events in this sample comparable to surveys conducted on other community samples (Breslau et al., 1998; Kessler, Sonnega, Bromet, & Nelson, 1995). Assessments of stressful events that occurred during the years following 9/11/01 were conducted on the sample annually. Continuous counts of the number of SLE experienced in childhood, adulthood, and during each of three years following 9/11/01 were computed. Events directly related to physical health status (e.g., suffered a serious accident, illness) were excluded from the analyses to avoid confounding stress with health outcomes.

Respondent's tendency to somatize was assessed annually via the somatization subscale of the Brief Symptom Inventory-18 (Derogatis, 2001), a well-validated and reliable measure of somatization. Reliability was excellent at all waves (all  $\alpha = .81$ ).

### Overview of analyses

Statistical analyses were conducted with STATA 10.1. Data were weighted to adjust for differences in the probabilities of selection and non-response both within and between households. Post-stratification weights were calculated by deriving weighted sample distributions along combinations of gender, age, race/ethnicity, region, metropolitan status, and education (Silver et al., 2002). The STATA Generalized Linear Model (GLM) module was

used to identify predictors of (a) the number health ailments reported over three years post-9/11 and (b) health care utilization over two years following 9/11. GLM allows population-averaged weighting for complex longitudinal survey data and provides necessary adjustments of standard errors for within subjects analyses. Two longitudinal outcomes were created for these analyses using respondents' annual reports across the years following 9/11: total number of health ailments (Table 1) and frequency of physician visits for physical health problems (Table 2). As the longitudinal physical health outcome was comprised of overdispersed count variables, the analyses were specified for a negative binomial distribution with clustering to adjust standard errors for within-subject correlations on repeated measures (Cohen, Cohen, West, & Aiken, 2003). As changes in cardiovascular ailments after 9/11 were examined previously by Holman et al. (2008), physical health outcome analyses were conducted with – and repeated without – cardiovascular ailments in the post-9/11 ailment totals; results were essentially identical to those reported in this paper. Table 1 reports analyses that include cardiovascular ailments in the total ailment count.

Four blocks of variables were tested for inclusion in the analyses: (1) demographics (i.e., gender, age, marital status, race/ethnicity, education, and income); (2) pre-9/11 MD-diagnosed physical health ailments; (3) pre-9/11 health risk factors (BMI, smoking status) and lifetime stressors; and (4) time-varying longitudinal covariates of (a) the number of pre- and post-9/11 MD-diagnosed mental health ailments; (b) post-9/11

somatization; and (c) post-9/11 stressors. These three longitudinal covariates were included in the adjusted model because they are theoretically relevant and likely alternative explanations for our findings. That is, individuals who somatize, have psychiatric illness, or report ongoing post-9/11 stress are likely to report more physical health problems and use more health care services and/or may be differentially impacted by 9/11-related exposure. In addition, ICD-9 categories of post-9/11 MD-diagnosed physical ailments were also examined as predictors of health care utilization after adjusting for the pre-9/11 physical health ailments.

Barring evidence of confounding, and to provide the most parsimonious model, variables that did not reach significance within blocks ( $p > .05$ ) were not included in the final models. All analyses included “time” as a covariate modeled to account for naturally-occurring changes in outcomes from pre- to post-9/11. Analyses were conducted twice with “time” coded continuously and then repeated with time coded categorically. Findings were not substantively different; for ease of presentation the continuous “time” analyses are reported. Interactions between “time” and other theoretically relevant predictors (e.g., age, 9/11-related exposure, lifetime and post-9/11 exposure to stress) were also tested to examine whether our findings were due to natural maturational changes in specific characteristics of our sample over time. No time-related maturational effects were identified.

**Table 2**  
Generalized Linear Model (GLM) Predicting Health Care Utilization Reported Over Two Years Following the 9/11 Terrorist Attacks\* ( $N = 1460$ ).

Predictor Variable	Model 1		Model 2	
	Beta (95% CI)	p value	Beta (95% CI)	p value
Time	.18 (.01–.35)	.004	.24 (.07–.40)	.005
Pre-9/11 Utilization	.67 (.54–.80)	<.001	.53 (.42–.65)	<.001
Pre-9/11 MD Diagnosed Physical Ailments	.38 (.27–.49)	<.001	.02 (–.09–.13)	.70
9/11-Related Exposure				
Live-TV vs. No live TV	.29 (.11–.48)	.002	.20 (.03–.38)	.025
Direct exposure vs. No live TV	.49 (.04–.93)	.031	.34 (–.12–.80)	.150
Age			.16 (.07–.25)	<.001
Ethnicity				
African-American			.37 (.01–.73)	.045
Hispanic/Latino			.60 (.17–1.04)	.006
Marital status				
Separated/Divorced			.77 (.04–1.50)	.039
Longitudinal Time-Varying Covariates				
# MD Diagnosed Mental Health Ailments			.22 (.12–.33)	<.001
BSI Somatization Subscale			.15 (.04–.25)	.008
Ongoing Stressors			.18 (.07–.29)	.001
Longitudinal Time-Varying Categories of Ailments				
# ICD-9 MD Diagnosed Cardiovascular			.29 (.20–.38)	<.001
# ICD-9 MD Diagnosed Endocrine			.14 (.06–.23)	<.001
# ICD-9 MD Diagnosed Gastrointestinal			.13 (.05–.21)	.001
# ICD-9 MD Diagnosed Hematology-Oncology			.13 (.04–.22)	.004

\*N of 1460 represents all individuals with complete data for the independent variables. Table 2 presents Standardized Betas for predictors of utilization of health care services over the two years following 9/11/01. Model 1 presents pre-9/11 health and 9/11-related exposure variables as predictors. Model 2 also includes (1) demographics, (2) longitudinal covariates representing ongoing stress, mental health, and somatization, and (3) specific ICD-9 categories of post-9/11 ailments that were significantly associated with increases in utilization over the 2 years post-9/11. The reference group for direct and live-TV exposure is those who had no live exposure to the attacks. The reference group for ethnicity includes European-American, Asian, and “other” ethnicities. Separated/divorced respondents are compared to all other respondents (married, single, widowed). Educational status and income are not included in the models as (a) they were not significantly associated with the outcomes and (b) effect estimates for variables of interest were essentially unchanged when they were included.

**Table 1**  
Generalized Linear Model (GLM) Predicting the Number of Physical Health Ailments Reported Over Three Years Following the 9/11 Terrorist Attacks\* ( $N = 1773$ ).

Predictor Variable	Model 1		Model 2	
	AIRR (95% CI)	p value	AIRR (95% CI)	p value
Time	1.19 (1.14–1.23)	<.001	1.18 (1.14–1.23)	<.001
# Pre-9/11 MD Diagnosed Physical Ailments	1.63 (1.58–1.69)	<.001	1.64 (1.55–1.73)	<.001
9/11-Related Exposure				
Live-TV vs. No live TV	1.18 (1.09–1.27)	<.001	1.11 (1.03–1.19)	.006
Direct exposure vs. No live TV	0.99 (0.85–1.16)	.923	1.02 (0.86–1.20)	.833
Age			1.20 (1.15–1.25)	<.001
Gender (male = 0, female = 1)			1.12 (1.04–1.20)	.001
Smoking Status			1.11 (1.04–1.18)	.002
Ex-smokers				
# Lifetime Stressors as Adult			1.10 (1.06–1.14)	<.001
Longitudinal Time-Varying Covariates				
# MD Diagnosed Mental Health Ailments			1.13 (1.09–1.17)	<.001
BSI Somatization Subscale			1.08 (1.05–1.12)	<.001
Ongoing Stressors			1.05 (1.01–1.08)	.004
Interaction terms				
Pre-9/11 Physical Ailments by Live TV Exposure			0.84 (0.79–0.89)	<.001

\*N of 1773 represents all individuals with complete data for the independent variables. Table 1 presents Adjusted Incident Rate Ratios (AIRR) adjusted for all other variables in the models. 95% confidence intervals are in parentheses. Adjusted Incident Rate Ratios (AIRR) reflect the rate at which MD-diagnosed ailments increase for each standard deviation unit increase in the predictor after adjusting for covariates in the model. The outcome is a longitudinal variable created from annual reports of MD-diagnosed ailments. Model 1 presents pre-9/11 health and 9/11-related exposure variables as predictors. Model 2 also presents (1) demographics; (2) health risk factors; and (3) longitudinal covariates of ongoing mental health, somatization, and stress that were significantly associated with increases in physical ailments over the 3 years post-9/11. The reference group for direct and live-TV exposure is those who had no live exposure to the attacks. Gender reference group is male. Reference group for smoking status is all others. Ethnicity, educational status, and income are not included in the models as (a) they were not significantly associated with the outcomes and (b) effect estimates for variables of interest were essentially unchanged when they were included.

For each of the longitudinal outcomes (i.e., physical health ailments and health care utilization), the first model presented includes “time”, pre-9/11 MD-diagnosed physical health ailments, and 9/11-related exposure as predictors; Model 2 includes significant control variables from the blocks described above. The second model for utilization was run two ways: once adjusting for the *individual* pre-9/11 ailments linked to the associated significant ICD-9 categories (i.e., pre-9/11 cardiovascular, GI, endocrine, and hematology-oncology) and again using the total count of pre-9/11 physical ailments including all ailments. The results were essentially identical for both approaches so the more parsimonious model is presented in Table 2. Table 1 presents adjusted incident rate ratios (AIRR) and Table 2 presents standardized beta coefficients as the relative effect size for each outcome.

## Results

### Sample

On 9/11/01, 1.6% respondents lived in Washington DC, 4.1% respondents lived within 25 miles of the WTC, 6.0% lived between 25 and 100 miles, 21.1% lived between 100 and 500 miles, 28.7% lived between 500 and 1000 miles, and 40.1% lived over 1000 miles from the WTC. Comparison of the demographic breakdown of participants from the pre-9/11 health survey through the 3-year annual follow-up survey with Current Population Survey (CPS) benchmarks from the U.S. Census Bureau suggests that we succeeded in obtaining a representative sample of the U.S. population with respect to key demographics (see Holman et al., 2008). Most weighted differences are within sampling error, although lower to middle-income households are over-represented. Most respondents watched the attacks live on television (62.9%), one third reported no live or direct exposure to the attacks (32.6%), and a small minority reported direct exposure (4.5%).

### Analysis of non-participants

Eligible individuals who were fielded the pre-9/11 health survey and completed it ( $N = 2592$ ) were not significantly different from non-respondents on age, gender, marital status, ethnicity/race, education, or income.

Individuals with complete data who were included in the GLM analyses were not significantly different from respondents with incomplete demographic, 9/11 exposure, or stressful life event data in terms of gender, marital status, income, or pre-9/11 mental or physical health status. Respondents with complete data were, however, slightly older ( $M = 50.6$  years vs.  $M = 42.5$  years,  $t[2585] = 21.84$ ,  $p < .001$ ), less likely to be African-American ( $\chi^2[1] = 21.83$ ,  $p < .001$ ), and had completed more years of education than respondents with incomplete data ( $\chi^2[4] = 54.49$ ,  $p < .001$ ).

### Overall rates of physical ailments

The proportion of the sample reporting at least one physician-diagnosed physical ailment over the 3-year period rose from 79.2% (pre-9/11, weighted 78.8%) to 89.5% (3-yrs post-9/11, weighted 88.7%). Within-subjects analyses indicate a significant increase in total physical health ailments over time (IRR = 1.19, 95% CI 1.14–1.24). After adjusting for demographics, pre-9/11 ailments, health risk factors, longitudinal covariates (somatization, mental health, and stressful event exposure), and 9/11-related exposure, the overall incidence of physical health ailments increased 18% over the three years after 9/11 (AIRR 1.18; 95% CI 1.14–1.23; see Table 1). Subsequent analyses of individual ICD-9-based categories of ailments revealed that all but one of the categories (genitourinary)

significantly increased pre- to 3-years post-9/11 (IRRs 1.10–1.44). To address whether the increase in ailments over time was an artifact of a maturing sample, interactions between “time” and other theoretically relevant predictors (e.g., age, 9/11-related exposure, stressful event history, post-9/11 stress) were tested. No time-related interactions were significant (all  $ps > .10$ ), suggesting that the increase in physical health ailments over the three years is not simply due to sample maturation. The main effects for time and the other theoretically relevant predictors remained significant ( $p < .001$ ) in these analyses.

### Health care utilization

Rates of health care utilization increased significantly over the two years following 9/11: 80.1% (pre-9/11, weighted 78.8%) to 87.4% (2-yrs post-9/11, weighted 86.3%) ( $\beta = .22$ , 95% CI .07–.36,  $p = .004$ ). Subsequent analysis revealed that increases in several categories of ICD-9 ailments after 9/11 helped explain increased utilization: cardiovascular, endocrine, gastrointestinal, and hematology-oncology ailments were all significant predictors of increased utilization in the 2 years following 9/11, even after adjusting for pre-9/11 health care utilization, pre-9/11 physical health, demographics, longitudinal covariates (somatization, ongoing stress, and mental health) and 9/11-related exposure (see Table 2, Model 2). None of the theoretically relevant predictors significantly interacted with time in these analyses.

### 9/11-related exposure and health

We examined the relationship between exposure to the attacks and increased incidence of both post-9/11 physical ailments (Table 1) and health care utilization (Table 2).

When compared to individuals who learned about the attacks only after they happened (i.e., no live media exposure), those who watched the attacks live on TV reported a 28% increased incidence of physical ailments (IRR = 1.28, 95% CI 1.18–1.39) over three years following 9/11. There were no significant differences in reports of post-9/11 ailments between those individuals with no live media exposure and the small minority of respondents with direct exposure to the 9/11 attacks. When demographics, pre-9/11 ailments, health risk factors, post-9/11 somatization, mental health ailments, and stressful event exposure were included in the model, the findings remained significant (IRR for live TV = 1.11, 95% CI 1.03–1.19).

The relationship between post-9/11 physical health and 9/11-related exposure was partially qualified by respondents' pre-9/11 physical health status. Individuals who reported higher levels of pre-9/11 physical health problems were more likely to see the 9/11 attacks live on TV ( $\chi^2[2] = 76.59$ ,  $p < .001$ ). As the effect of 9/11-related exposure was not eliminated when pre-9/11 physical ailments were included in the model (suggesting this is not a mediated relationship), we tested whether the relationship between 9/11-related exposure and post-9/11 physical ailments was moderated by respondents' pre-9/11 health status. Fig. 1 plots the significant interaction using a median split for pre-9/11 physical health ailments to demonstrate the effect: As 9/11-related exposure increased for individuals in the top half of pre-9/11 physical health problems, post-9/11 health ailments increased linearly and significantly ( $b = .66$ ,  $p < .0001$ ). As 9/11-related exposure increased for individuals in the bottom half of pre-9/11 physical health problems, post-9/11 health problems also increased significantly, but the slope for change in post-9/11 physical ailments was significantly smaller ( $b = .24$ ,  $p < .002$ ). Importantly, the main effect for 9/11-related exposure remained significant in these analyses (see Table 1).

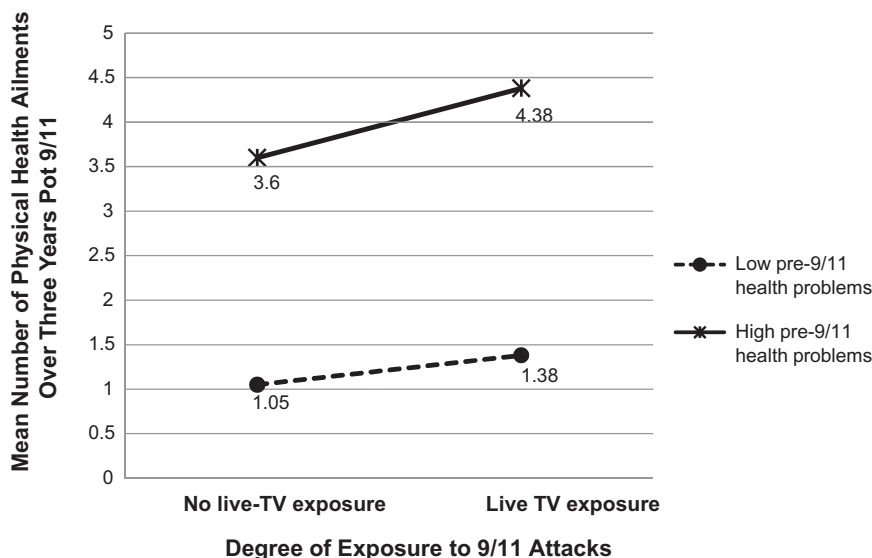


Fig. 1. Mean number of physical health ailments over three years post-9/11 by 9/11-related exposure and pre-9/11 health ailments.

After adjusting for pre-9/11 health care utilization and pre-9/11 physical health, both direct and live media exposure to the attacks predicted significantly higher utilization over the subsequent 2 years (see Table 2, Model 1). After adjusting for pre-9/11 health care utilization, pre-9/11 physical health, demographics, longitudinal covariates (somatization, ongoing stress, and mental health), and significant ICD-9 categories of ailments, live media exposure continued to predict increased utilization over the two years following 9/11 (Table 2, Model 2).

## Discussion

The September 11th terrorist attacks have been linked with several mental and physical health problems ranging from anxiety to stroke in samples of individuals either directly exposed to the attacks, involved in the clean-up, or living in the New York metropolitan area (Brackbill et al., 2006; Fagan et al., 2003; Wheeler et al., 2007). In the present study, the use of a large, representative national sample and the longitudinal collection of health ailments before and after the 9/11 attacks provided us with a unique opportunity to examine rates of physical health problems and health care utilization in the aftermath of 9/11 nationwide. We demonstrated an increase in reports of physical health problems and higher rates of health care utilization in individuals from across the U.S. following 9/11, even after adjusting for theoretically relevant covariates, demographics, and time-related changes in our outcomes. In addition, 9/11-related exposure was associated with higher rates of post-9/11 physical ailments and utilization in the years following 9/11. As our findings remained robust after testing interactions with time that may reflect maturational effects (e.g., age, stressful event history, ongoing stress), we have accounted for many changes in health over time that could be related to maturational processes.

Prior research addressing the connection between extreme stress and physical health has typically assumed that *direct* exposure or development of PTSD are necessary preconditions that link stressful experiences with health conditions (Fagan et al., 2003; Kubzansky, Koenen, Spiro, Vokonas, & Sparrow, 2007; Schnurr & Green, 2004). For example, adults who survived in collapsed or seriously damaged buildings during the WTC attacks reported new physical health ailments after 9/11, including respiratory, GI, neurologic, and dermatologic problems (Brackbill et al., 2006).

Since most of our respondents' exposure involved watching the attacks live on television, our data go one step further by suggesting the possible public health impact of *indirect* exposure to extreme stress. The sudden, unexpected, and uncontrollable nature of the attacks may have strengthened their negative impact on health, with mass media coverage spreading the impact of 9/11 geographically (Wright, Ursano, Bartone, & Ingraham, 1990). Indeed, we found that those who watched the attacks live on TV were more likely to report an increase in physical health ailments over time. This finding was most pronounced for individuals who experienced high levels of pre-9/11 health problems. In essence, individuals reporting more pre-9/11 physical health problems were vulnerable to live TV exposure, whereas individuals with the fewest pre-9/11 physical health problems were less vulnerable to low levels of exposure.

Our findings also highlight the importance of not underestimating the health and societal impact of collective stress. Not only did we find an overall increase in physical health problems following 9/11, but these problems contributed to higher rates of health care utilization, which is likely to increase health care costs. Understanding the biopsychosocial processes that link *indirect* exposure to collective stress with these health outcomes and developing interventions to promote public health and prevent disease following events like the 9/11 attacks would be an important area for future research (McEwen, 2007).

Finding that ongoing post-9/11 stressors were also persistently associated with physical ailments and utilization is consistent with theories suggesting that negative events may produce chronically stressful conditions or alter brain structure, function, or biochemistry, rendering individuals vulnerable to long-term negative health problems (Charney, 2004; McEwen, 1998). Highly stressful events are important not only because they may create disabling mental distress, but also because they may promote or aggravate life threatening physical conditions, increase utilization of services, and diminish individuals' quality of life.

## Contributions and limitations

This study has several strengths. Its prospective and longitudinal nature enabled us to examine changes in rates of health problems following the 9/11 attacks and explore the relationship between these physical ailments and health care utilization in

a broad national sample of individuals exposed to a collective stressor. We were able to identify specific ICD-9 categories of ailments most closely associated with increases in utilization. Post-9/11 stressors were included as a covariate in our statistical models to control for differential levels of post-9/11 stress that may have contributed to subsequent health problems. Finally, our health measure had been benchmarked against the NHIS, which itself has been validated against medical records.

Nonetheless, self-report measures of physician-diagnosed physical ailments and health care utilization are subject to recall biases and reflect the respondents' interpretations of their medical encounters. Future research should confirm self-reports using medical records of health care visits and include biological markers of stress and disease to document the pathways by which collective stress impacts the disease process. We were also unable to assess health care utilization beyond two years post-9/11 so we do not know whether the patterns identified extended beyond that time. We did not have a pre-9/11 or longitudinal assessment of health insurance status; future studies should include a thorough, longitudinal assessment of insurance status to determine how it influences the utilization of health care services. In addition, although our initial sample was close to the U.S. population census on most demographic characteristics, younger, Black, less-educated respondents were more likely to drop out of the study over time, making it difficult to generalize our findings to these groups.

Because we studied a national sample of U.S. residents, most of whom were *indirectly* exposed to the 9/11 attacks, we have a limited range of exposure – very few with direct exposure, and no one unexposed. This limited our power to detect the effects of direct exposure on health outcomes, especially three years after the attacks. Nonetheless, we found that indirect exposure to the 9/11 attacks via the media was associated with increased health problems and utilization over time. Finally, while we maintain that the changes in health found after 9/11 were related to the collective trauma of the terrorist attacks, we acknowledge that this collective stress was not measured directly. However, as our findings are robust when controlling for potential maturational effects, we are confident that the increases in health ailments reported over time by our sample reflect more than merely health changes expected to be seen in an aging sample.

## Conclusions and future directions

Many advances have been made in understanding the mental and physical health effects of extreme stress. We extend this work by documenting an increase in rates of physical health ailments in a national sample following the 9/11 attacks that is associated with increases in health care utilization, and we specify categories of ailments associated with these increases. Future research should address differential predictors of specific categories of ailments, including the different types of ongoing stress associated with these ailments. As we have demonstrated these associations in a sample of individuals who were predominantly *indirectly* exposed to a shared extreme event, future research should examine similarities as well as potential differences in the mechanisms by which stress may produce serious health problems in both directly and indirectly exposed individuals. In so doing, researchers may find new ways to intervene to prevent health problems in the general population following collective stress.

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