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Impact of Hurricanes and Floodings on Mental Health Outcomes Within the United States: A Systematic Review and Meta-Analysis

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Abstract

Objective: Given the US population concentration near coastal areas and increased flooding due to climate change, public health professionals must recognize the psychological burden resulting from exposure to natural hazards.

Methods: We performed a systematic search of databases to identify articles with a clearly defined comparison group consisting of either pre-exposure measurements in a disaster-exposed population or disaster-unexposed controls, and assessment of mental health, including but not limited to, depression, post-traumatic stress (PTS), and anxiety.

Results: Twenty-five studies, with a combined total of n =616 657 people were included in a systematic review, and 11 studies with a total of 2012 people were included in a meta-analysis of 3 mental health outcomes. Meta-analytic findings included a positive association between disaster exposure and PTS (n = 5, g = 0.44, 95% CI 0.04, 0.85), as well as depression (n = 9, g = 0.28, 95% CI 0.04, 0.53), and no meaningful effect size in studies assessing anxiety (n = 6, g = 0.05 95% CI −0.30, 0.19).

Conclusions: Hurricanes and flooding were consistently associated with increased depression and PTS in studies with comparison groups representing individuals unaffected by hazards.

Background/Rationale

Flooding is the most common type of disaster, with more than 2 billion people affected worldwide between 1998 and 2017.[1] Between 2020-2022, 60 weather and climate disasters affected the US, with losses exceeding $1 billion (USD) each.[2] Approximately 3% of the US population lives in areas subject to 1% annual chance coastal flood hazard.[3] Projections for the Atlantic and eastern North Pacific Oceans include increased hurricane rainfall and intensity.[4] As climate change increases, the number of people impacted by climate-related hazards grows.[5]

Extreme weather and climate-related events can have lasting mental health consequences, especially if these events cause loss of income and resources or community relocation.[4] Hazard-related events range from property loss to displacement from home and community. In a sample of 810 persons exposed to Hurricane Katrina, the prevalence of post-traumatic stress disorder (PTSD) in the 2 years following the hurricane was 22.5%, while predictors of PTSD included hurricane-related financial loss, post-disaster stressors, and post-disaster traumatic events.[6]

However, there is a lack of epidemiological evidence on the mental health impact of hurricanes and flooding. Many research findings have relied on cross-sectional data or studies lacking a pre-disaster assessment or appropriate control group. This methodological limitation may result in biased findings. An understanding of the literature assessing the mental health impact of natural hazards has become increasingly important and relevant for disaster response planning.

Previous systematic reviews of mental health outcomes after disasters have assessed a variety of natural hazards, including earthquakes,[7,8] flooding,[9] and exposure to any type of disaster[11,10–14] The present review focuses exclusively on studies concerning exposure to hurricane and/or flooding. Other types of natural and human-induced disasters—such as terrorism, train derailments, and earthquakes—lack time for preparation and evacuation common before a

hurricane or flood. The preparation and evacuation stage may influence the risk of mental health outcomes in survivors in a unique way as people with more resources may mitigate negative outcomes by evacuating[6]—an option not available to those who are exposed to sudden-onset hazards such as earthquakes or tornadoes. Prior research has shown a differential impact on communities affected by hurricanes, indicating characteristics of community-level factors (such as economic development and social capital) are important predictors of post-disaster mental health.[15,16]

To examine whether hurricane and/or flood exposure increases negative mental health outcomes, we reviewed studies focused exclusively on populations exposed to either hurricanes or floods. We limited our analysis to US studies to account for consistent warnings from the National Weather System, uniform disaster relief resources, responses from Federal Emergency Management Agency, and standardized insurance regulations for natural hazard damage.

Objectives

We performed a systematic review and a meta-analysis of the evidence base of changes in depression, anxiety, and post-traumatic stress (PTS), along with other mental health outcomes in people impacted by hurricanes and floods. We sought to quantify the evidence of mental health impacts of exposure to hurricanes and floods in studies within the US where mental health outcomes were compared to pre-disaster measurements or unexposed controls.

Methods

The study protocol for this systematic review and meta-analysis was registered with PROSPERO (registration number 2021 CRD42021291101). Study design and reporting is guided by the Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines[17] and the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) checklist.[18] Quality assessment was performed using the New Castle-Ottawa Scale (NOS).[19]

Study Identification and Selection

We conducted a systematic literature search for English-language research articles on mental disorders and/or suicide and hurricane and floods occurring in the United States published any time. The search was conducted in September 2021 and updated in March 2023 (Supplementary Tables S1 and S2 include details of the search criteria). We did not use restrictions on publication date to capture as many unique events as possible.

Study Inclusion and Study Selection

We included peer-reviewed articles where the study population experienced exposure to a hurricane, storm, and/or flooding, and the design included measurement of at least 1 psychological measure assessed in people affected by disaster, compared with an unaffected comparison group or a pre-disaster assessment in the same person. Articles including interventions, participants under age 10, commentaries, and reviews or articles not in English were excluded (Supplemental Table 1).

Reviewers (VM, KF, MS, EA) used Covidence software (Covidence, Veritas Health Innovation, Melbourne, Australia) to screen 6758 abstracts for inclusion. Data extraction was performed independently by VM, with 50% of studies selected by duplication of, and independently reviewed by, KF, MS, and EA. Conflicts were resolved by group consensus.

Quality Assessment

Quality assessment of articles was performed (by VM, and duplicated by KF, MM, and IA) using the Newcastle-Ottawa Scale (NOS).[19] Criteria for evaluating case-control studies, cross-sectional, and longitudinal studies were used to classify studies into high, medium, or low risk of bias based on NOS cumulative scoring.

Effect Measures

We extracted mean scores from validated scales measuring mental health outcomes. The construct measured (depression, anxiety, PTS, or other mental health outcomes), instrument, mean score, and standard deviation were extracted for the unexposed group (or pre-disaster group) and the exposed group (or post-disaster group), along with the number of people in each group (see Supplemental Table 3 for example data extraction).

Meta-Analysis Model

Due to variability in instruments used to assess depression, anxiety, and PTS, we used standardized mean difference (SMD) estimates with 95% confidence intervals to compare results across different instruments assessing the same psychological construct.

To assess the association between hurricanes and floods and each of the 3 outcomes, we calculated an overall effect size for each outcome by applying a random-effects model to mean scores. A random-effects model was applied to analyze pooled means scores by mental health outcome. Heterogeneity was assessed and forest plots with 95% confidence intervals were produced for all studies that reported key outcomes with means and standard deviations. Standardized mean differences (Hedge's g) range from 0 to 1. We used the commonly prescribed cut points of Hedge's g at 0.20, 0.50, and 0.80 to describe small, medium, and large effect, respectively.[20]

Variability between studies was assessed with the calculation of I^2, measuring heterogeneity across meta-analyses, the standard deviation tau (τ) and variance of heterogeneity τ^2 to measure the total amount of systematic differences in effects across studies.[21] I^2 is often presented as a ratio of true heterogeneity to total variance across the observed effect estimates. A small value of I^2 indicates the effect size is comparable across studies in the meta-analysis, and a larger I^2 signals substantial difference across studies.[22] I^2 values range from 0-100, with suggested benchmarks of 25%, 50%, and 75% as low, moderate, and high.[23,24] The meta-analysis was conducted using Stata (Stata Corp, Texas Station). The meta-analysis models included subgrouping by study design. We followed guidance to not visually assess funnel plots for publication bias under these conditions.[25] Separate analyses were conducted restricting studies to only those that measured outcomes within 12 months of the hurricane or flood.

Results

Study Selection

We identified 7742 abstracts and performed full-text review of 859 articles (Figure 1). Of the 859 articles, 25 articles met stated inclusion criteria with responses from a combined total of $n = 616\,657$ people (Table 1).

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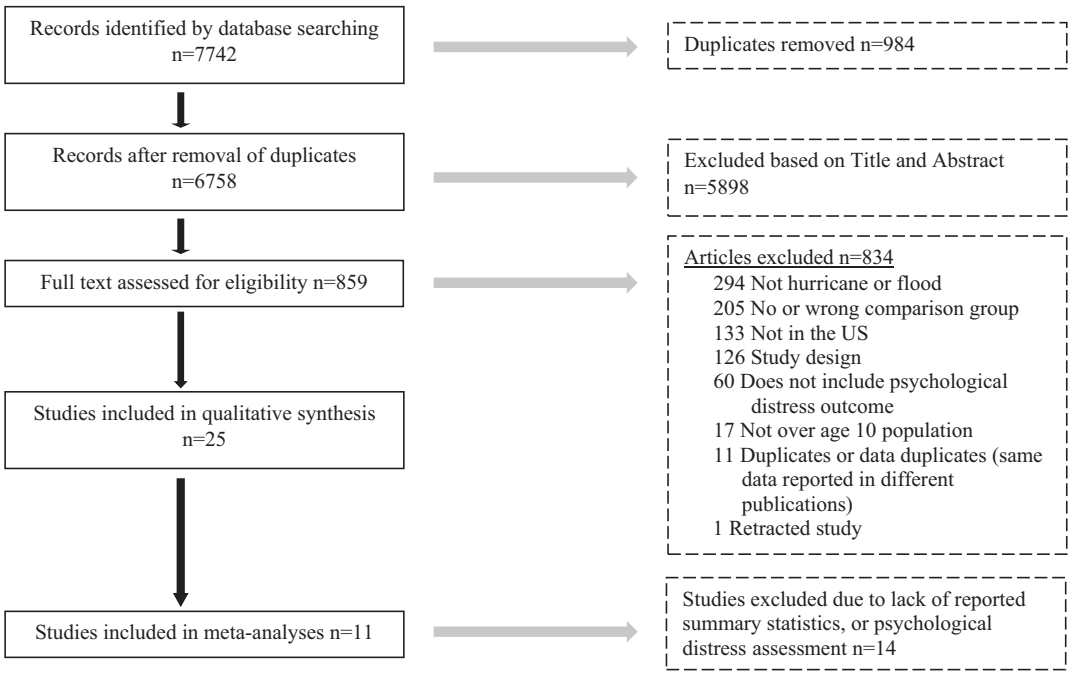

Figure 1. PRISMA flowchart of study selection. PRISMA flow chart of study selection for systematic review of the association between hurricane and flooding disasters and psychological distress. Contact with authors was not made due to the length of time since publication.

Study Characteristics

Eight case-control studies,[26–33] 12 cohort studies, and 6 cross-sectional or panel studies contained a valid control group and an assessment of a mental health outcome. The most assessed outcome was depression (n = 13 studies), 8 studies assessed anxiety, and 7 studies measured PTS (Table 1).

More than half of the studies in the sample (n = 17) focused on the 2005 disaster Hurricane Katrina (Global identifier number [GLIDE] #TC-2005-000144-USA), 3 of which also included Hurricane Rita (GLIDE #TC-2005-000163-USA), which made landfall in the month following Hurricane Katrina, exposing many people to 2 storms. Four studies concentrated on other hurricanes or tropical storms (Hurricane Andrew [GLIDE #TC-1992-000002-USA], Hurricane Michael [GLIDE #TC-2018-000433-USA], Hurricane Maria [GLIDE #TC-2018-000433-USA] and Tropical Storm/Hurricane Agnes [GLIDE #TC-1972-000002-USA]). The remaining 4 studies focused on flooding in Baton Rouge, LA (GLIDE #FL-2016-000145-USA), Puerto Rico (1985), North Dakota (1997), and Iowa (FL-1993-000005-USA). Global identifiers were not available for the flooding in Puerto Rico in 1985 and North Dakota in 1997.

Quality Assessment

Seven studies were rated as low risk of bias/high quality, 3 of these were case-control studies (Table 1). Five studies received a medium quality rating, 3 of which were case-control studies. The remaining studies (n = 13) were rated as high risk of bias/low quality or unable to assess. Typical issues of quality assessment were lack of a reported response rate, lack of information about missing values, and questions about the representativeness of the cases in case-control studies. One study reporting attrition in the sample found that only 30% of the original sample was able to be located and assessed for follow up.[34] Unfortunately, this study was one of the few that reported pre- and post-PTS symptoms assessments in a cohort. Pre-disaster assessments were performed in a range from less than 1 month[35] to 2 years before disaster.[36] Post-disaster assessments were performed in a range from 1 month[28,37] to 5 years after disaster,[29,38] and 2[26,39] studies failed to report the time of assessment relative to disaster.

Exposure Assessment

The primary method of exposure assessment was geographic (n = 14 studies), with descriptions ranging from state-level to residence within a 40-mile (64.4 km) radius of the storm path. Among these, 6 studies also assessed self-reported disaster exposure. Four studies recruited individuals displaced by flooding or storm damage, with some case-control studies recruiting participants directly from relocation camps. Seven studies utilized self-reported exposure measures, all incorporating standardized instruments for reporting of traumatic events experienced during or after a disaster, such as the Hurricane-Related Traumatic Experiences Questionnaire[40] or the Survey of Exposure to Hurricanes and their Aftermath.[34]

Depression

Out of 25 studies, 13 (52%) measured depression for a combined population of n = 4086 people. Study sample sizes ranged from 42 to 1735 participants. Studies assessing depression included 6 case-control designs, 5 cohort studies, and 2 cross-sectional mean comparison studies. Eight studies were excluded from the meta-analysis; studies were excluded when either the authors did not report both mean and standard deviation estimates, and/or the authors only reported the percent of people who met a pre-specified cut-point. For example, Ferraro[41] reported that 8% and 9.5% of the sample were diagnosed with depression pre- and post-disaster, respectively. The most used instrument was the Center for Epidemiologic Studies Depression scale (CES-D), used by 4 studies. Ten studies (77%) reported increased depression scores in people who were exposed

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Table 1. Studies included in review presented by study type, *n* = 25

Author	Disaster, year	Design	Sampling	Sample size	Disaster exposure	Time since disaster (months)	*n* (%) Female	Race/Ethnicity	Outcome ascertainment	Risk of bias	Direction of effect	Included in meta-analysis?
Cherry et al., 2021[26]	Baton Rouge, LA flooding, 2016	Case-control	Convenience older adults mean age 49.6 years	134	Self-report	NR	NR	NR	PHQ–9	Medium	↑	Y
						NR			PSWQ		↑	Y
						NR			PCL-C		↑	Y
Davis et al., 2010[27]	Hurricane Katrina, 2005	Case-control	Convenience University students, mean age 20.8 years	136	Students displaced due to hurricane	3	NR	Caucasian 59%, African American 41%	DASS-Depression	Low	↑	Y
									DASS-Anxiety		↑	Y
									DASS-Stress		↑	N
									PCL-C		–	Y
Ginexi et al., 2000[28]	Iowa floods, 1993	Case-control	Iowa Health Poll	1733	Self-report	1–3	65.70%	White 93%	CES-D	Low	↑	Y
									Percent with diagnosed depression		↑	N
McLeish and Del Ben, 2008[45]	Hurricane Katrina, 2005	case-control	Convenience sample of psychiatric patients at an outpatient clinic, *n* = 76 assessed a month before Katrina, *n* = 80 assessed 1 month after, mean age 41 years	156	Geographic; Self-report storm impact	1	110 (70.5%)	Caucasian *n* = 96 (66%)	CES-D	Unclear	↑	Y
									PCL-C		__	N
Melick et al., 1985[29]	Tropical Storm Agnes, 1972	Case-control	Convenience, older females ages 65–86, *n* = 122 flood exposed, *n* = 45 controls	167	Geographic- town	60	100%	NR	Zung SDS	High	↓	N
									SCL–90 anxiety		↓	N
									SCL–90 depression		↓	N
									Langer score		↓	N
Stanko KE, 2019[30]	Hurricane Katrina, 2005	Case-control	LSU Flood Study	202	Controls for "indirectly affected comparison who did not experience structural damage to their home in the flood"	9	*n* = 150 (74.3%)	NR	SF–36 MCS	Low	↑	N
Tucker et al., 2008[31]	Hurricane Katrina, 2005	Case-control	Convenience, 22 adult survivors and 20 adult controls, mean age 33.5 years	42	Cases were survivors who were relocated to Oklahoma; exposure to hurricane and flooding was assessed	17	Survivors *n* = 14 (63.6%), Controls *n* = 13 (65.0%)	African American survivors *n* = 19 (86%), controls *n* = 17 (85%); White survivors *n* = 3 (14%), controls *n* = 3 (15%)	BDI	Medium	↑	Y

(*Continued*)

Table 1. (*Continued*)

Author	Disaster, year	Design	Sampling	Sample size	Disaster exposure	Time since disaster (months)	*n* (%) Female	Race/Ethnicity	Outcome ascertainment	Risk of bias	Direction of effect	Included in meta-analysis?
									PTSD Scale		↑	Y
Vigil, 2007[32]	Hurricane Katrina, 2005	Case-control	convenience sample of young adults ages 11–22 from relocation camp, matched with non-exposed controls on SES, age, and sex	131	living in relocation camp specifically for Katrina survivors	2	*n* = 83 (63.3%)	93% African American	CES-D	Low	↑	Y
									IES-R		↑	Y
									RCMAS		↓	Y
									Satisfaction with life scale		↓	N
									Current Thoughts Scale		↓	N
									Rosenberg Self-Esteem Scale		↓	N
Walling et al., 2020[33]	Hurricane Katrina, 2005	Case-control	Convenience sample from a relocation camp	61	Geographic	12	NR	Exposed African American 91%, unexposed controls African American 90%	BDI	Medium	↑	N
									Clinician administered PTSD scale (CAPS)		↑	N
Abramson et al., 2010[38]	Hurricanes Katrina and Rita, 2005	Cohort	NHIS for pre-disaster and CGAFH used for post-disaster	283	Geographic	60	NR	NR	SDQ	High	↑	N
									Emotional Problems		↑	N
Arkin, 2022[48]	Katrina, 2005	Cohort	RISK	231	Geographic	144	"Primarily female"	Non-Hispanic Black *n* = 195 (84%)	K6 Scale	High	↑	N
Brown et al., 2010[37]	Hurricanes Katrina and Rita, 2005	Cohort	Louisiana Healthy Aging Study	59	Geographic	1–4 months, 6–12 months later	52.50%	Caucasian 89.8%, African American 10.2%	SF–36 Mental Health Score	Low	↓	N
Canino et al., 1990[46]	Puerto Rico floods, 1985	Cohort	Probability sampling	375	Geographic	24	55.50%	NR	Diagnostic Interview Schedule/Disaster Supplement	Low	↑	N
									Diagnostic Interview Schedule/Disaster Supplement Depressive		↑	Y
Costa et al., 2009[34]	Hurricane Katrina, 2005	Cohort	Convenience sample from an existing study of youth (ages 6–17) and their parents	74	Self-report, survey	either 5–7 months or 12 months after	41.90%	Caucasian 60%, African American 30%, Hispanic 8%, Asian 1%, other 1%	RCADS-Youth Anxiety	Medium	↑	Y
									PTSD Checklist		↑	Y
Ferraro et al., 1999[41]	North Dakota flooding, 1997	Cohort	Convenience sample of elderly adults	57	Self-reported flood damage	12–18	n = 43 (63.2)	NR	Geriatric depression scale short form	High	↑	N

(*Continued*)

Table 1. (*Continued*)

Author	Disaster, year	Design	Sampling	Sample size	Disaster exposure	Time since disaster (months)	*n* (%) Female	Race/Ethnicity	Outcome ascertainment	Risk of bias	Direction of effect	Included in meta-analysis?
Fincham and May 2021 [43]	Hurricane Michael, 2018	Cohort	Existing cohort of undergraduate students	269	Geographic, college campus; self-report hurricane Impact	1	*n* = 254 (94.4%)	European American 69.9%, African-American 10.8%, Hispanic 14.5%, Asian 3.3%, Other 4.1%	DASS–21	High	↓	N
La Greca et al., 1998[40]	Hurricane Andrew, 1992	Cohort	Unclear	92	Geographic—school; hurricane exposure assessed	3–7	42 (46%)	White 45 (49%), African American 35 (38%), Hispanic 11 (12%), Asian 1 (1%)	RCMAS	Unclear	↓	Y
									Social anxiety Scale for Children		↓	N
Mattei et al., 2022 [63]	Hurricane Maria, 2017	Cohort	2 cohorts: PRADLAD and PROSPECT	87	Geographic	5	62 (71.3%)	Puerto Rican *n* = 73 (83.9%)	CES-D	High	↓	Y
Rodes et al., 2010[42]	Hurricane Katrina, 2005	Cohort	Opening doors study	392	All exposed, disaster experience assessed	7–19	95.90%	African American 84%, non-Hispanic White 11%	PSS > 7	Medium	↑	N
									K6 >7		↑	N
									K6>12		↑	N
Vu and Vanlandinham, 2012[35]	Hurricane Katrina, 2005	Cohort	Population register of Vietnamese American households in the greater New Orleans area between ages 20–54	128	Self-reported home damaged by Katrina	12	43 (33.6%)	Vietnamese 100%	Vietnamese depression scale	Low	↑	N
									SF–36 Mental Component Score		↓	N
									SF–36 Mental Health Score		↓	N
Weems et al., 2007[44]	Hurricane Katrina, 2005	Cohort	Convenience sample of adolescents from a larger study pool at the University of New Orleans mean age 11.4 years	52	Geographic—living in greater New Orleans at the time of the storm	6–7	22 (42%)	European American *n* = 33 (64%); African American *n* = 15 (29%); Other *n* = 4 (7%)	RCADS-MD	High—pre-hurricane data was collected on 173 participants who were not able to be contacted for follow-up	↓	Y
									Child PTSD Checklist		↓	Y
									RCADS-GAD		–	Y
An et al., 2019[49]	Hurricane Katrina, 2005	Panel study (mean comparison)	BRFSS	70267	Geographic-State level	12	62%	White 78.9%, African American 13.7%, Hispanic 3.6%, Asian 1.2%, other, or multiracial 2.7%	Number of poor mental health days	High	↑	N

(*Continued*)

Table 1. (*Continued*)

Author	Disaster, year	Design	Sampling	Sample size	Disaster exposure	Time since disaster (months)	*n* (%) Female	Race/Ethnicity	Outcome ascertainment	Risk of bias	Direction of effect	Included in meta-analysis?
Kessler et al., 2006[36]	Hurricane Katrina, 2005	Panel study (mean comparison)	National Comorbidity Survey-Replication and post-Katrina survey	1849	Geographic-Census divisions	4–6	NR	NR	K6 score of 13–24	Low	↑	N
									K6 score>7		↑	N
									Suicidal ideation		↓	N
									Suicide plan		↓	N
									Suicide attempt		–	N
Mukherjee et al., 2017[50]	Hurricanes Katrina and Rita, 2005	Panel study (mean comparison)	BRFSS Louisiana and study data	12598	Geographic—parish designated by IRS as a disaster area for extended tax relief	12–24	52%	White 62%; Black or African American 26%; Hispanic 5%; Other 5%	Mental distress days	High	↑	N
Zahran et al., 2011[39]	Hurricanes Katrina and Rita, 2005	Panel study (mean comparison)	People living in areas hit by Hurricane Katrina and/or Rita enrolled in BRFSS and interviewed either before or after the date of hurricane landfall	527082	Geographic	Unknown	NR	NR	Poor mental health days	High	↑	N

NR, Not Reported; PHQ-9, Patient Health Questionnaire-9; PSQW, Penn State Worry Questionnaire; PCL-C, Post-traumatic Checklist-Civilian; DASS, Depression, Anxiety and Stress Scale; Zung SDS, Zung Self-Rating Depression Scale; SCL-90, Symptom Checklist; BDI, Beck Depression Inventory; CES-D, Center for Epidemiologic Studies Depression Scale; IES-R, Impact of Events Scale-Revised; RCMAS, Revised Children's Manifest Anxiety Scale; CAPS, Clinician administered PTSD scale; SDQ, Strengths and Difficulties Questionnaire; SF-36, Short Form 36; RCADS, Revised Child Anxiety and Depression Scales, Child and Parent Version; PSS, Perceived Stress Scale; K6, Kessler Psychological Distress Scale; RCMAS, Revised Children's Manifest Anxiety Scale; RCADS-MD, Revised Child Anxiety and Depression Scales, Major Depression; RCADS-GA, Revised Child Anxiety and Depression Scales, Generalized Anxiety

to disasters. Twelve studies included information about the length of time between the hurricane or flood and assessment; the minimum time was 1 month, the maximum time was 60 months (mean = 13 months, SD = 15 months). Regarding quality assessment, all studies that reported an increase in depression in people exposed to flooding or hurricanes were assessed as low or medium risk of bias.

Anxiety

Nine studies measured anxiety with a total of $n = 1447$ individuals and sample size ranging from 52 to 392 people. Six studies included anxiety assessments that met inclusion criteria for the meta-analysis. One study was excluded because the anxiety measure (the Perceived Stress Scale) was reported as prevalence of the sample with a score above a cutoff score of 7, with 20% of the cohort meeting this threshold 1 year before hurricane exposure; 31% met this criteria between 7-19 months after exposure.[42] Another excluded study reported higher scores on the Symptom Checklist (SCL-90) Anxiety subscale in controls compared to Tropical Storm Agnes exposed cases (scores 17 vs. 15, respectively), but standard deviations were not reported.[29] Also excluded was a study in which the authors reported the results of the Depression, Anxiety and Stress Scale (DASS-21) as a single score instead of reporting the anxiety subscale.[43] The authors reported a decrease in the single summary score indicating a decrease in depression, anxiety, and stress in the time period after exposure to Hurricane Michael. Fifty percent of studies assessing anxiety enrolled children older than 10 or adolescents. The mean age of participants ranged from 11.3 years[34,44] to 49.6 years,[26] and 1 study enrolled fourth through sixth grade children but did not include a mean age of the sample.[40] Four studies of 9 assessing anxiety reported increased anxiety in those exposed to disaster, 1 study reported no difference between the 2 groups, and 3 studies found lower anxiety scores in exposed relative to controls or pre-disaster comparisons. However, out of these 4 studies which reported an increase in symptoms, only 1 was assessed as having low risk of bias.[32]

Post-Traumatic Stress

Eight studies measured PTS, 6 of which were included in the meta-analysis. Of the 2 studies not included in the meta-analysis, 1 reported an increase in PTS in unexposed compared with exposed persons, but did not report standard deviations along with mean scores,[33] and the other study did not report mean scores from the PTSD Checklist for Civilians (PCL-C), but reported no difference in scores in people who were exposed compared to the unexposed.[45] Two cohort studies (both assessing people exposed to Hurricane Katrina less than 1 year after the hurricane) performed pre-disaster and post-disaster assessment of PTS, but the studies had divergent findings. One study found an increase in PTS symptoms in youths and their parents[34] while another study found no increase in PTS in adolescents.[44] Four case-control studies found an increase in PTS in the exposed compared to the unexposed.[26,31–33] Only studies that conducted diagnostic interviews[46] specifically stated that the outcome of interest was related to hurricane or flood experience. Standardized questionnaires like the PCL-C do not specify an index event but instead ask about PTS symptoms in the previous 30 days.[47]

Global Mental Health Status and Other Outcomes

Several studies included global measures of mental health status, such as results from the Kessler Screening Scale for Psychological Distress (K6), the mental composite score from the SF-36, number of poor mental health days, and suicide behavior. None of these studies were included in the meta-analysis due to small numbers and inconsistent reporting. Two cohort studies found increased prevalence of psychological distress defined by K6 scores above pre-defined cut-points in the post-exposure groups.[42,48] One study used K6 scores pre- and post-Hurricane Katrina in 1849 people and found increased prevalence of severe mental illness post-hurricane (6.1% to 11.3%) and increased mild-moderate mental illness (15.7% to 31.2%).[36] This study was the only one to include suicide-related outcomes. The authors found that in people with serious mental illness, the prevalence of suicidal ideation decreased from 8.4% pre-Katrina to 0.7% post-Katrina, and suicide plans dropped from 3.6% to 0.4%, while no difference was found in the percentage of people reporting a suicide attempt, which the authors hypothesize could reflect protective factors activated by the hurricane.[36] Two studies reported an increase in the psychological SF-36 Mental Health Composite Score (MCS), indicating an increase in negative mental health symptoms, but increases were small and not statistically significant.[35,37] One case-control study observed a decrease in the MCS, indicating improved mental health in people unexposed to a hurricane.[30] Three studies used cross-sectional panel data to compare the number of poor mental health days or mental distress days, with 2 studies finding small increases in poor mental health days in geographic regions impacted by Hurricane Katrina.[39,49] A study using statewide data from Louisiana found a decrease in the population reporting no mental distress days from 76% to 69% comparing the year prior to Hurricanes Katrina and Rita to the year after the storms.[50]

Meta-Analysis of Depression, Anxiety, and PTS

Eleven of the 25 studies were included in the meta-analysis. Reasons for excluding studies were: (1) not including standard deviations along with means for groups;[29,41,49,51] (2) reporting percentages representing prevalence;[33,35,36,38,42,50] and (3) reporting only a global mental health status score.[37,39] Overall, results of the meta-analysis suggest there was evidence of increased depression and PTS symptoms in people with disaster exposure, but no evidence for a change in anxiety symptoms. Results of the meta-analysis found depression scores were increased in those who were exposed to a disaster compared to the unexposed (k = 9; g = 0.28; 95% CI 0.04, 0.53). There was high heterogeneity in effect sizes in studies: $I^2 = 88.5\%$, $\tau^2 = 0.17$, Q_{resid} (8) = 33.9, $P < 0.01$ (Figure 2). The meta-analysis resulted in no meaningful change in anxiety scores associated with disaster exposure (k = 6; g = -0.05; 95% CI −0.30, 0.19). There was moderate heterogeneity in effect sizes across studies: $I^2 = 69\%$, $\tau^2 = 0.06$, Q_{resid} (5) = 15.73, $P < 0.01$ (Figure 3).

Regarding disaster exposure and PTS (Figure 4), exposure was associated with increased PTS (k = 6; g = 0.44; 95% CI 0.13, 0.76). There was high heterogeneity in effect sizes across studies of PTS symptoms: $I^2 = 76\%$, $\tau^2 = 0.11$, Q_{resid} (5) = 17.57, $P = 0.0035$.

Sensitivity analyses

After excluding 1 study that assessed participants more than 12 months after exposure, the association with depression changed from g = 0.82 (95% CI 0.04, 0.53) to g = 0.15 (95% CI −0.085, 0.375). Repeating the meta-analysis for anxiety after excluding 1 study, altered the result from g = −0.05 (95% CI −0.30, 0.19) to g = −0.12; (95% CI −0.37, 0.12). Excluding 2 studies from the PTS meta-analysis, left 4 studies, changing the association with PTS

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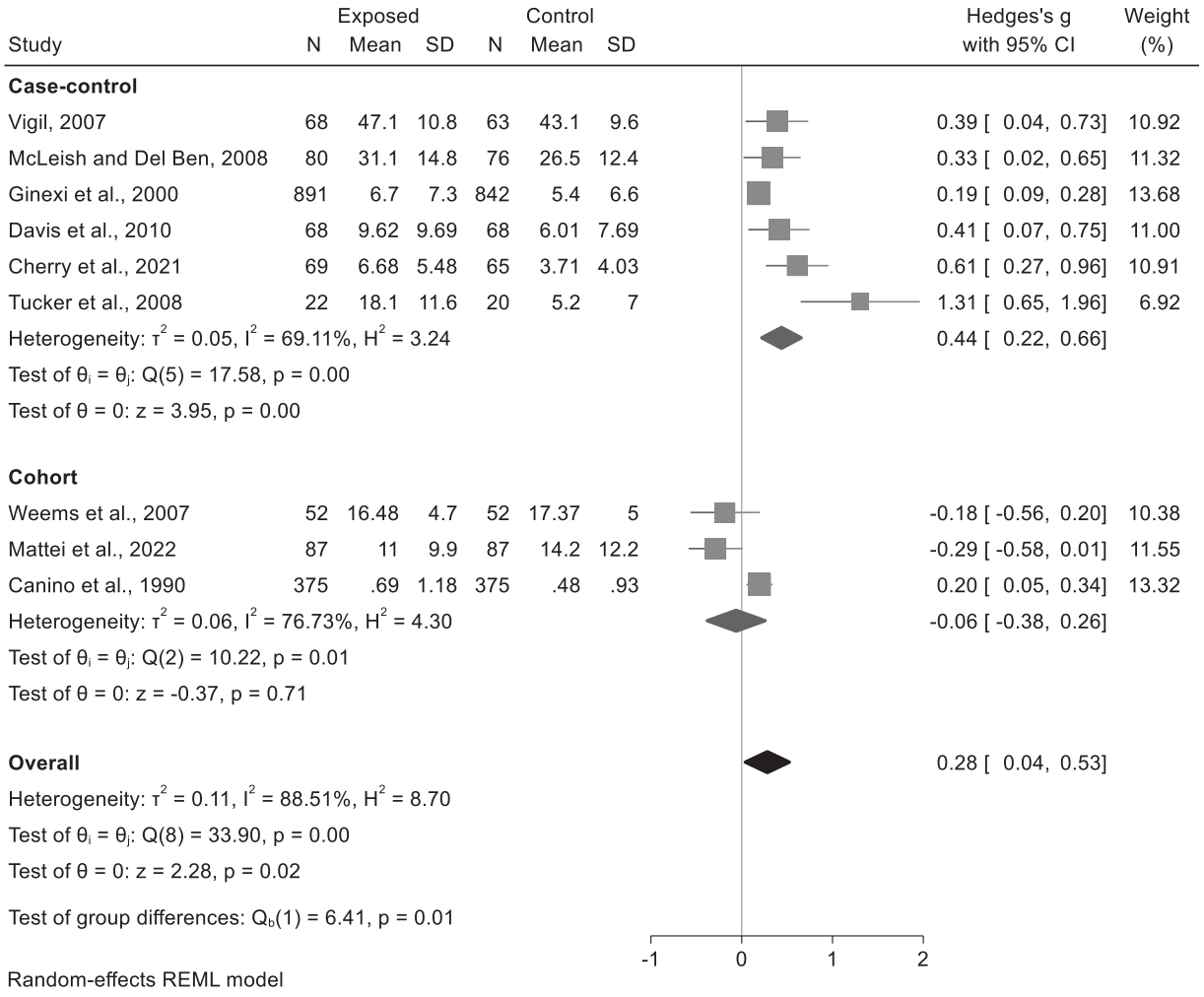

Figure 2. Studies assessing depression symptoms (n = 9), grouped by study design.

symptoms from g = 0.44 (95% CI 0.13, 0.76) to g = 0.27; 95% CI −0.01, 0.54).

Discussion

Summary of Meta-Analysis Findings

In this meta-analysis we reported differences in mental health outcomes in persons exposed to hurricane and flood disasters. We restricted our review to include only research studied with findings based on an unexposed control group or a pre-post design for adequate comparison after previous systematic reviews research identified methodological limitation.[12,52–54] We found an increase in PTS symptoms and depression when comparing unexposed and exposed groups, but no meaningful difference in anxiety scores. Results of recent publications using meta-analyses have summarized results varying from no effect of disasters on mental health outcomes, to a small or medium effect.[12,13,52,53,56,57–59] One meta-analysis including multiple study types and multiple disaster types found a point estimate of mental health disorders after flood disaster across 9 countries to be 7%, and prevalence of PTSD to be between 3% and 52%.[55] A meta-analysis focused on flood survivors experiencing PTSD estimated the prevalence to be 29%, but none of the included studies were from the United States.[59] Our findings are consistent with those of Beaglehole et al.,[14] who performed a meta-analysis of studies measuring psychological distress after any type of disaster, and found a standardized mean difference between exposed and non-exposed groups or pre- and post-groups to be 0.63 (95% CI 0.27, 0.98). However, a limitation of previous studies is the use of any mental health outcome under the umbrella of "psychological distress," while our study identified each outcome separately to disentangle differences across these outcomes. Our study adds focus on 3 major psychological symptoms (depression, anxiety, and PTS) and was limited to hurricanes and floods within the United States. The variability in our meta-analytic findings and the heterogeneity in these studies reflects the complexity of measuring psychological outcomes in different populations and emphasizes the uniqueness of psychological constructs of depression, anxiety, and PTS.

Interpretation

This finding supports the conclusion that depression and PTS are elevated in hurricane and flood survivors. The meta-analytic finding suggests a moderate effect size for PTS symptoms, with lower effect size for depression, and no effect in assessment of anxiety. The assumption underlying the interpretation of the standardized

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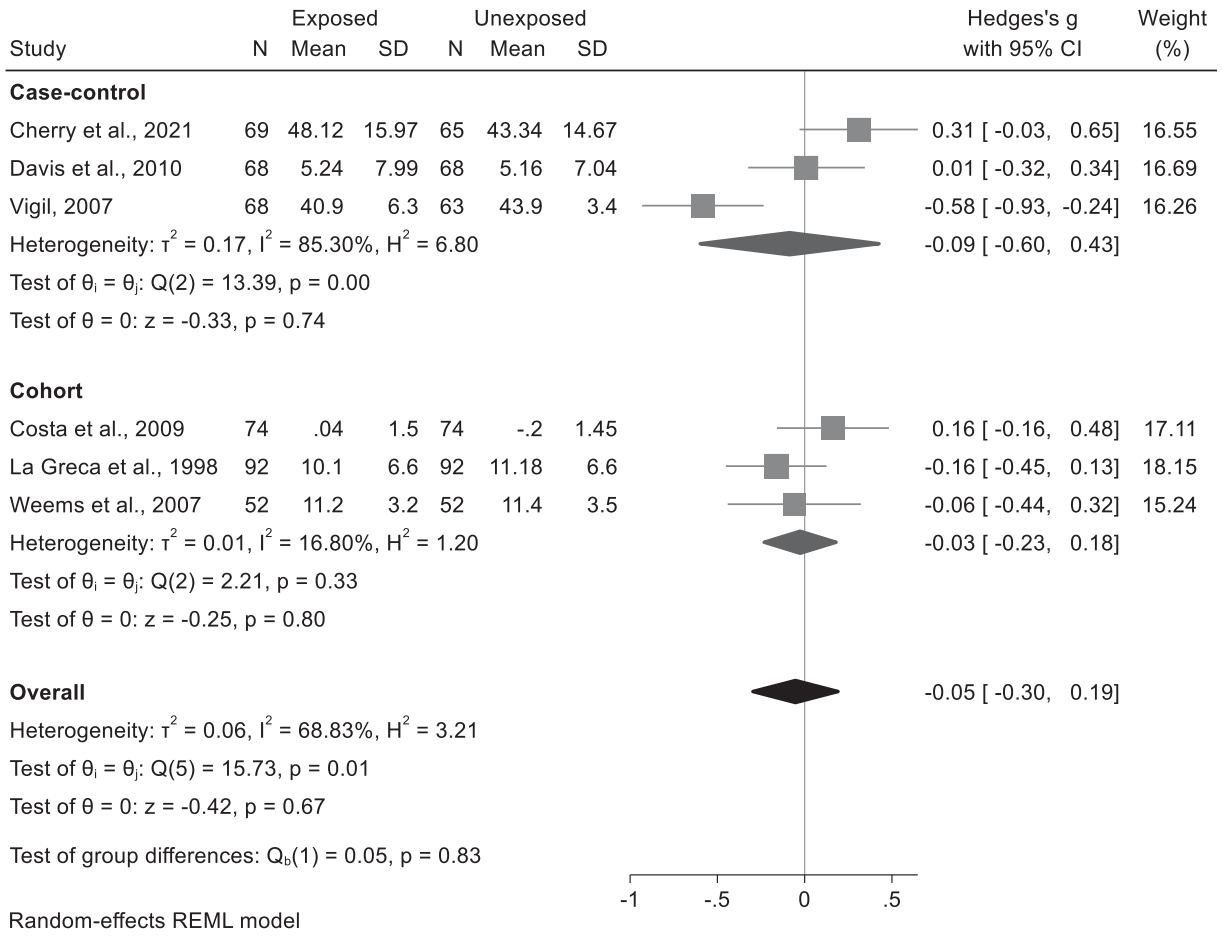

Figure 3. Studies assessing anxiety symptoms (n = 6), grouped by study design.

effect size Hedges' g is that if all mean scores were transformed to a scale where the standard deviation is equal to 1 within-groups, then we expect to see an increase in PTS in the exposed compared to the unexposed of 0.44 on this scale. The larger effect size for PTS compared with depression or anxiety might be due to PTS questionnaires assessing symptoms that do not map onto anxiety and depression, and those symptoms (detachment, re-experiencing) may account for the difference.

Mean differences were larger in case-control studies compared to cohort studies. It is not clear which studies informed participants about the goal of the study, indicating the potential participants in case-control studies could be subject to recall bias, with people experiencing hazards more likely to notice psychological symptoms and attribute changes in mental health as related to disaster exposure.[60] Cohort studies are not immune to bias; exposed participants could have been more likely to report psychological symptoms. Attrition of participants is a large problem for follow-up when populations have been displaced or displacement occurs differentially, introducing bias when those who are most vulnerable to poor mental health may also be those who are most vulnerable to displacement and severe disruption. The degree to which post-traumatic growth mediates the development of negative mental health outcomes in those exposed to disaster is outside the scope of this review, but studies have explored the complex relationship among psychological factors that decrease negative psychological outcomes in those who experience traumatic exposures.[61,62] Similarly, studies that assessed PTS did not clearly define an index event of traumatic exposure and given the prevalence of PTS prior to hurricane or flood exposure, therefore it is difficult to determine if individuals were responding to questions about symptoms related to exposure to a hurricane or flood, or if they were reporting symptoms beginning after an unrelated traumatic event.

Studies included in this systematic review assessed outcomes at varying lengths of time after the disaster. These differences in time to assessment make comparisons challenging. We performed additional analysis restricted to studies that only included assessments less than 12 months after the exposure. Findings from these additional analyses resulted in no statistically significant finding of the association between exposure to hurricanes and/or floods and the outcomes of depression, anxiety, or PTS. The change in point estimates for studies measuring PTS suggests that PTS symptoms could take longer to develop, or suggest individuals experienced sustained trauma over time (such as displacement or continued financial hardship).

Limitations

A lack of studies with low risk of bias was a limitation of the publications reviewed. Only 7 studies (28%) scored as low risk of bias according to our quality assessment. There were no studies included in the meta-analysis of anxiety or PTS with a sample size

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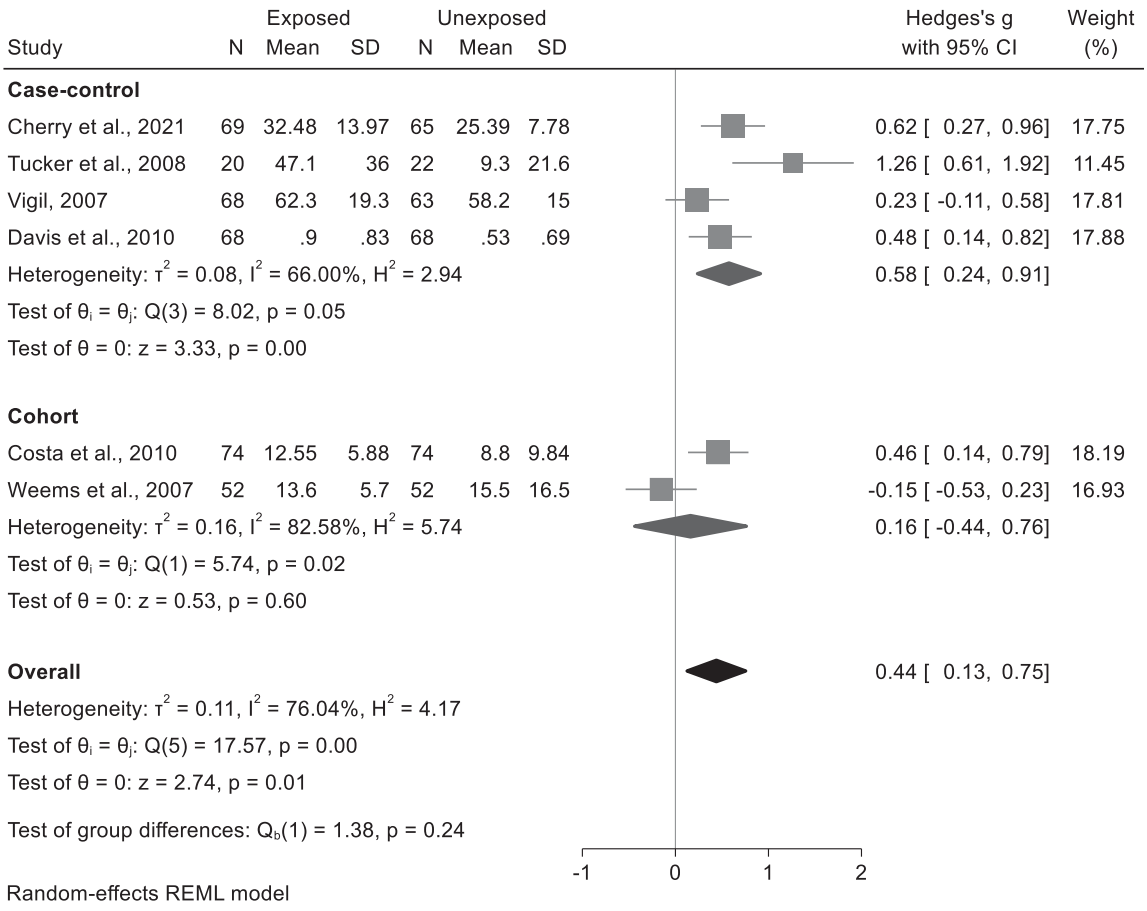

Figure 4. Studies assessing PTSD symptoms (n = 6), grouped by study design.

larger than 200 people. Conclusions based on a relatively small sample size should be approached with caution. Seventeen of 25 (68%) studies reviewed focused on Hurricane Katrina, including 6 of 11 (55%) studies included in the meta-analysis. This may provide a heterogeneous level of exposure that strengthens the findings but reduces generalizability to other hurricanes and floods impacting different regions.

In the absence of standardized assessment and reporting around the mental health impact of hurricanes and floods, our study is the best possible synthesis of the evidence base. Future research should structure post-disaster assessments around time-points that have clinical relevance for both the onset and the persistence of mental health outcomes. Future studies should focus on larger sample sizes; however, this recommendation requires deployment of prepared research strategies and "just-in-time" resources to mobilize data collection efforts. Of particular importance is the need to assess suicide-related outcomes.

Conclusion

Hurricanes and flooding cause significant loss of life, property, wages, and time, disrupting daily life for all ages. These events are linked to increased depression and PTS, and as climate change makes such events more frequent, the prevalence of related mental health issues is expected to rise. Differences in psychological outcomes highlight the need to measure depression, anxiety, and PTS separately, as each requires distinct therapeutic approaches. Tailored mental health interventions are crucial for helping survivors cope and rebuild. Enhancing mental health resources and awareness in hazard-prone areas may improve resilience.[55,58] Mental health support should be central to disaster preparedness and recovery efforts to prevent long-term disability and reduced quality of life.

Supplementary material. To view supplementary material for this article, please visit http://doi.org/10.1017/dmp.2024.327.

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Competing interest. The authors report no conflicts of interest.

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