

RESEARCH ARTICLE

The cumulative contribution of direct and indirect traumas to the production of PTSD

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Abstract

Objective

Posttraumatic Stress Disorder (PTSD) affects millions of people worldwide. While the relationship between direct exposure to traumatic events and PTSD is well-established, the influence of indirect trauma exposure on PTSD remains unclear. It is similarly unclear what role cumulative exposure to direct and indirect traumas play in the risk of PTSD.

Methods

The study uses data from the Houston Trauma and Recovery Study, conducted on 2020–2021, and involved a random sampling of 1,167 individuals residing in Houston during Hurricane Harvey in 2017. Participants were asked about their experiences related to both Hurricane Harvey and the subsequent COVID-19 pandemic. Exposures were categorized as direct or indirect traumas, in line with the criteria delineated in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5). Cumulative exposures were also calculated.

Results

Among participants, 12.6% were experiencing current PTSD. There were significant associations between both direct [OR = 3.18, 95% CI 1.85, 5.46] and indirect [OR = 1.91, 95% CI 1.05, 3.46] traumas related to Harvey, as well as direct [OR = 2.13, 95% CI 1.20, 3.77] and indirect [OR = 1.69, 95% CI 0.93, 3.09] traumas due to COVID and the risk of PTSD in fully adjusted models. Further, significant associations were found between the cumulative exposure to traumas from both Hurricane Harvey and COVID-19 and the risk of PTSD, considering both direct [OR = 2.53, 95% CI 1.36, 4.70] and indirect exposures [OR = 2.79, 95% CI 1.47, 5.28].

Conclusions

Our study offers support for connections between exposure to both direct and indirect traumas stemming from large-scale disasters and PTSD. Moreover, we show that cumulative exposures to multiple large-scale events increase the risk of PTSD. This highlights the

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Data Availability Statement: We would like to share the data used in this manuscript. However, in consultation with our Institutional Review Board at Boston University School of Medicine, we have determined that we cannot share the entire data set used in this analysis, outside our study team, even in deidentified form. Our study protocol included a data sharing consent form, per guidelines of the National Institute of Mental Health, and approximately 80% of the people in our study sample declined to provide permission to share their deidentified data. Thus, we could only feasibly share data outside of our study team from about

20% of participants, which would not allow study replication. The point of contact to the Institutional review board at Boston University Medical Campus is the email: medirb@bu.edu.

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Abbreviations: DSM, Diagnostic and Statistical Manual of Mental Disorders; HTRS, Houston Trauma and Recovery Study; PTSD, Post Traumatic Stress Disorder.

importance of the consideration of a range of exposures as risks for PTSD, particularly in a time of compounding disasters and broad population exposures to these events.

Introduction

Posttraumatic Stress Disorder (PTSD) is a recognized psychiatric disorder affecting millions of people worldwide [1–7]. Evidence shows connections between a range of traumatic event exposures and PTSD, including exposure to inter-personal traumas (e.g., violence) and large-scale natural disasters [8, 9]. However, fundamental questions remain regarding the nature of traumatic events that can lead to PTSD.

A firmly established connection exists between direct exposure to traumatic events, such as natural disasters, life-threatening accidents, physical and sexual assaults, military combat, war exposure, life-threatening illnesses, and the traumatic loss of a loved one, and the susceptibility to PTSD [1–4, 8].

Other work has suggested that indirect traumatic events might also lead to greater risk of PTSD [10–14]. The concept of indirect trauma was initially introduced in the literature through the terms "secondary traumatization" and "vicarious traumatization," and defined as the experience of trauma indirectly affecting a family member, a close friend, a therapy client [10] or the exposure to trauma indirectly while performing professional duties, such as those carried out by emergency rescue crews [11]. In the 2013 5th version of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), a change was introduced in the definition of PTSD, incorporating indirect exposure to trauma into diagnosis criterion A (Exposure Criterion), defined as the "Indirect exposure to aversive details of the trauma, usually in the course of professional duties (e.g., first responders, medics)" [15, 16]. The DSM-5 excluded other potential forms of indirect trauma, such as observing traumatic events through electronic media, television, video games, or pictures, from its definition [17–19].

It remains unclear, however, the role these indirect traumatic events play in shaping PTSD. Some researchers have raised questions about the validity of including indirect exposure in the definition of PTSD [20, 21], while others have supported the concept [3].

A second, and related question pertains to the role of additive traumatic experiences to the risk of PTSD [22, 23], and whether cumulative exposure to direct and indirect traumatic events similarly increase the risk of PTSD [24–26]. Theory and research suggest that prior encounters with traumatic events can heighten sensitivity to adverse consequences when facing subsequent potentially traumatic events [27]. Substantial evidence emerges on the cumulative exposure to childhood traumas influencing the subsequent development of PTSD [28]. Research also suggests a dose-response relationship between the number of childhood traumas and comorbid psychiatric problems, including PTSD, in certain populations [29]. Cumulative exposure models to traumatic events suggest a dose-response relationship [30–32]. To our knowledge, there has been no previous work that had specifically examined the cumulative effects of indirect traumatic exposures on PTSD.

Our study seeks to investigate the impact of exposure to both direct and indirect traumas, as well as cumulative trauma, on PTSD, within the context of Houston, Texas where residents experienced the large-scale natural disaster of Hurricane Harvey, followed by the COVID-19 pandemic.

In August 2017, Hurricane Harvey, classified as a Category 4 storm on the Saffir-Simpson hurricane scale, hit Texas and Louisiana upon reaching land, establishing itself as one of the most severe tropical cyclones in the history of the United States [33]. The hurricane led to 68

direct fatalities and 35 deaths attributed to indirect causes, causing flooding in over 300,000 structures and affecting up to 500,000 cars. Additionally, approximately 336,000 households lost power, and 40,000 flood victims were either displaced or sought refuge in shelters, resulting in an estimated total of \$125 billion in damages [34].

Three years later, the COVID-19 pandemic emerged as a protracted natural disaster [35]. Alongside more than 770 million confirmed cases and nearly 7 million confirmed deaths [36], the pandemic introduced a variety of social and economic challenges that are strongly linked to PTSD within the general population [37], among those directly exposed and hospitalized [38], as well as among healthcare workers experiencing indirect exposures [39].

These two disasters presented an opportunity to study the impact of exposures to direct and indirect traumas, as well as the cumulative impact of these traumas on PTSD among individuals in Houston who faced both Hurricane Harvey and the subsequent COVID-19 pandemic.

Materials and methods

This study examined the exposure to both direct and indirect trauma during Hurricane Harvey and the COVID-19 pandemic and explored their relationship with the probable diagnosis of PTSD.

Study sample

The Houston Trauma and Recovery Study (HTRS) is an observational survey that employed random address-based sampling of residents from 88 neighborhoods in Houston, officially recognized by the city municipality as super-neighborhoods [40]. Out of 12,009 addresses to which recruitment letters were sent, 899 were identified as invalid. Participants were recruited from November 17th 2020 to August 24th 2021. Among the 11,110 eligible participants who received the letters, the study saw the participation of 1,266 individuals, yielding a comprehensive response rate of 11.4%. Out of the 1,266 participants, 1,167 were residents of Houston during Hurricane Harvey and constitute the sample for our study.

Tools

Participants invited to take part in the study could opt to either complete a paper survey sent by mail or engage in a web-based survey. The questionnaire consisted of eight sections: Section A consisted of 25 questions on Hurricane Harvey experiences; section B consisted of 3 questions on potentially traumatic events; section C consisted of 20 questions on problems after potentially traumatic events; section D consisted of 9 questions on emotional health; Section E consisted of 5 questions on health between the Hurricane Harvey and COVID-19 pandemic; section F consisted of 30 questions on COVID-19 pandemic experiences; section G consisted of 2 questions on experiences in the last two weeks; and section H consisted of 12 demographic questions. Some of the sections included subsections. The survey was accessible in both English and Spanish.

We created intricate survey weights to consider factors such as the likelihood of inclusion in the survey, survey response probability, neighborhood size, and the number of adults per household. In the last phase of the weighting process, we adjusted these weights to match the demographic distributions of sex, race, ethnicity, age, and educational attainment in the Houston Metro Area as of 2020 [41]. Additionally, to tackle the effects of missing data, we conducted multivariable multiple imputation on 15 sets of data. Subsequently, we synthesized these datasets to generate consolidated estimates, which we present [42].

Study constructs

Trauma. Participants were queried about their experiences in relation to Hurricane Harvey and COVID-19. We categorized these exposures based on their direct or indirect nature adhering to the criteria outlined in DSM-5. Direct exposures encompassed experiences of directly witnessing or personally experiencing a traumatic event, whereas indirect exposures pertained to the traumatic experiences of their loved ones [12]. In constructing each of the below trauma subvariables, we summed included factors and used a median split to generate binary variables, as shown in [S1 Table](#).

Harvey-related direct trauma. Direct traumas related to Hurricane Harvey included experiencing a serious injury due to the hurricane and worrying about being seriously injured or killed while being away from Houston.

Harvey-related indirect trauma. Indirect traumas included worries about the serious injury or death of family members or close friends, a family member or close friend suffering a serious injury, and a family member or close friend passing away.

COVID-related direct trauma. For COVID, the Direct Traumas included four factors: becoming seriously ill from COVID, being hospitalized due to COVID, having a fear of contracting COVID, and fearing death from COVID.

COVID-related indirect trauma. For COVID, indirect trauma included having family members or close friends who became seriously ill or died from COVID, as well as worrying about the possibility of family members or close friends succumbing to COVID.

Cumulative exposure. The cumulative exposure was defined as the sum of exposures falling within a specific category, both within Hurricane Harvey and COVID, for either direct or indirect trauma.

Demographics. Participants were asked to provide information on several demographic attributes. They were queried about their gender, with response options, including male, female, or 'other'. Age was collected as a continuous variable. Educational attainment was divided into two categories: high school or less, and some college or higher. Marital status options encompassed being married, divorced or separated, or never married. Ethnicity was assessed as Hispanic or non-Hispanic, while race was categorized as White, Black, Asian, American Indian or Alaska Native, and Native Hawaiian or Other Pacific Islander. These racial and ethnic categories were further grouped into White non-Hispanic, Black non-Hispanic, Other non-Hispanic, and Hispanic. Income categories for the year 2019 were delineated as follows: <\$24,999; \$25,000-\$49,999; \$50,000-\$74,999; \$75,000-\$99,999; \$100,000-\$149,999; \$150,000-\$199,999; \$200,000+. Our analysis considered both the method of survey administration (mail or web) and the range of interview dates, corresponding to two distinct recruitment periods (11/17/20-3/31/21 or 4/1/21-8/24/21). Additionally, the count of children and adults in the household was included as supplementary covariates.

PTSD. Criteria outlined for DSM-5 PTSD [15] is met if participants fulfilled all five DSM-5 criteria for PTSD. These criteria comprise Criterion A (traumatic event), Criterion B (reexperiencing), Criterion C (avoidance and numbing), Criterion D (negative thoughts), and Criterion E (hyperarousal).

Initially, we assessed if participants fulfilled Criterion A (traumatic event), without requiring them to tie their symptoms to a specific event, in alignment with a growing body of literature [43]. To determine eligibility for Criterion A event, participants were asked whether they had personally experienced something highly stressful or if a family member or close friend had undergone such an event. We provided participants with a range of examples, encompassing natural disasters, fires, physical or sexual assault or abuse, combat exposure, encounters with death or threats to life, severe accidents, and life-threatening illnesses.

We then used the PTSD Checklist for DSM5 to establish whether participants met all DSM5 criteria for PTSD [44]. In the subsequent inquiries regarding specific symptoms, participants were asked to consider the events they previously thought about in relation to Criterion A, as well as any other highly stressful experiences they might have encountered. Symptoms were identified as present if marked as bothering a participant at least "moderately" [45].

We then proceeded to determine if participants met Criterion B (re-experiencing) by assessing the presence of one or more re-experiencing symptoms. Subsequently, we assessed whether participants met Criterion C (avoidance and numbing) by identifying the presence of one or more of these symptoms. Criterion D (negative thoughts) was evaluated by checking for the presence of two or more symptoms outlined in Criterion D, and Criterion E (hyperarousal) was assessed by verifying two or more Criterion E symptoms. Finally, we confirmed whether participants met all five DSM-5 criteria for probable PTSD.

Analysis

The data was analyzed in 2023. First, using descriptive statistics and chi-squared tests, we assessed whether demographics and trauma exposures are related to DSM-5 PTSD (see Table 1).

Table 1. Demographics (n = 1167)*.

| Exposure | Category | n (%) | Current PTSD n (%) | χ^2 ; p |
|------------------------------|------------------------|-------------|--------------------|--------------|
| Sex | Male | 408 (48.1) | 36 (38.4) | 5.58; <0.05 |
| | Female | 749 (50.5) | 98 (55.4) | |
| | Other | 10 (1.4) | 3 (6.2) | |
| Education | High school or less | 319 (47.9) | 52 (58.5) | 3.56; 0.06 |
| | Some college or higher | 848 (52.1) | 85 (41.5) | |
| Marital Status | Divorced/Separated | 338 (15.8) | 53 (25.1) | 5.88; <0.05 |
| | Never Married | 327 (34.0) | 48 (43.9) | |
| | Married | 502 (50.2) | 36 (31.0) | |
| Race/Ethnicity | White non-Hispanic | 425 (36.6) | 28 (18.4) | 6.12; <0.05 |
| | Black non-Hispanic | 301 (14.2) | 51 (29.2) | |
| | Other non-Hispanic | 101 (6.0) | 12 (6.1) | |
| | Hispanic | 340 (43.2) | 46 (46.3) | |
| Income | ≤\$24,999 | 277 (26.4) | 52 (41.3) | 2.46; <0.05 |
| | \$25,000-\$49,999 | 260 (22.1) | 33 (23.7) | |
| | \$50,000-\$74,999 | 161 (12.7) | 16 (8.1) | |
| | \$75,000-\$99,999 | 108 (8.7) | 13 (9.4) | |
| | \$100,000-\$149,999 | 116 (9.6) | 6 (5.3) | |
| | \$150,000-\$199,999 | 101 (8.3) | 9 (8.4) | |
| | \$200,000+ | 144 (12.3) | 7 (3.8) | |
| Survey Administration Method | Mail | 665 (48.1) | 87 (58.0) | 3.02; 0.08 |
| | Web | 502 (51.9) | 50 (42.0) | |
| Date of Interview | 11/17/20–3/31/21 | 584 (50.0) | 74 (52.3) | 0.16; 0.69 |
| | 4/1/21–8/24/21 | 583 (50.0) | 63 (47.7) | |
| Current Depression | Yes | 63 (5.8) | - | - |
| Current PTSD | Yes | 137 (12.6) | - | - |
| | No | 1030 (87.4) | - | - |

*Frequencies are unweighted; percentages, means and statistical measures are weighted

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Table 2. Associations between types of direct and indirect trauma and PTSD*.

| | Exposure | Category | PTSD | |
|---------|-----------------------------------|----------|-------------------|--------|
| | | | OR (95% CI) | P |
| Model 1 | Cumulative Harvey direct trauma | 0 | 1 | NA |
| | | 1–2 | 3.18 (1.85, 5.46) | < .001 |
| Model 2 | Cumulative Harvey indirect trauma | 0 | 1 | NA |
| | | 1–3 | 1.91 (1.05, 3.46) | .033 |
| Model 3 | Cumulative COVID direct trauma | 0 | 1 | NA |
| | | 1–4 | 2.13 (1.20, 3.77) | .010 |
| Model 4 | Cumulative COVID indirect trauma | 0–1 | 1 | NA |
| | | 2–3 | 1.69 (0.93, 3.09) | .088 |

*All Models adjusted for age, gender, race, education, marital status and income; Full models shown in [S2 Table](#).

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Next, we estimated multivariable logistic regressions with interaction tests to predict the adjusted associations between each category of trauma and PTSD, as shown in [Tables 2 and 3](#). These analyses were adjusted for age, gender, race, education, marital status, and income.

All analyses were performed using SAS 9.4 program, incorporating complex survey weights, with statistical significance set at $p < 0.05$.

The study received ethical approval from the institutional review board at Boston University Medical Campus, and all research methods adhered to the relevant guidelines and regulations. Consent was waived by the ethics committee.

Results

As shown in [Table 1](#), the majority of study participants identified as either male (48.1%) or female (50.5%), with a small minority (1.4%) selecting another gender category. More than half of the participants (52.1%) had attained some college education or higher, and approximately half (50.2%) were married. The sample consisted of 43.2% Hispanic individuals, 36.6% White non-Hispanic individuals, 14.2% Black non-Hispanic individuals, and 6% individuals from other non-Hispanic racial backgrounds. The average age of participants was 46.1 years. A substantial proportion of participants (61.2%) indicated a current income of less than \$75,000. The interview mode was evenly split between paper (i.e., mail) (48.1%) and web (51.9%). 12.6% of participants reported experiencing current PTSD.

Descriptive analysis of the data, shown in [S1 Table](#), reveals that a substantial portion of participants experienced a variety of exposures. For Hurricane Harvey, this included direct traumas, such as worrying about being seriously injured or killed (34.6%), and indirect trauma involving concerns about the serious injury or death of family members or

Table 3. Associations between cumulative direct and indirect trauma and PTSD*.

| | Exposure | Category | PTSD | |
|---------|---|----------|-------------------|------|
| | | | OR (95% CI) | P |
| Model 1 | Cumulative Harvey and COVID direct trauma | 0 | 1 | NA |
| | | 1–6 | 2.53 (1.36, 4.70) | .003 |
| Model 2 | Cumulative Harvey and COVID indirect trauma | 0–1 | 1 | NA |
| | | 2–6 | 2.79 (1.47, 5.28) | .002 |

* All Models adjusted for age, gender, race, education, marital status and income; Full models shown in [S4 Table](#).

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close friends (54.8%). Furthermore, a significant number of participants were exposed to COVID-related events, including direct trauma like the fear of contracting COVID (48.5%), and indirect trauma involving concerns that family members or close friends might die from COVID (64.6%), or the experience of having seriously ill family members or friends (39.6%) or losing family members and friends due to COVID (19.4%).

We noted an increased incidence of PTSD among individuals who experienced specific Hurricane Harvey exposures, including worry about serious injury or death during Harvey (direct trauma, 22.1%), and the death of family members or close friends (indirect trauma, 32.5%). Further, we noted a higher prevalence of PTSD among those who experienced certain COVID-related traumas, including hospitalization (direct trauma, 80.4%), and the death of family members or friends due to the pandemic (indirect trauma, 17.5%).

We found a greater likelihood of PTSD when individuals were exposed to a higher number of direct or indirect traumas, in accordance with the DSM-5 criteria. Prevalence and median splits are presented in [S1 Table](#).

[Table 2](#) shows the results of multiple logistic regression analyses examining the relationship between direct and indirect trauma exposure for each event and PTSD prevalence. These adjusted results reveal a statistically significant relationship between direct and indirect traumas related to Hurricane Harvey and COVID-19, and the presence of PTSD. These relationships were statistically significant in all categories except for cumulative COVID indirect trauma. Associations with PTSD were demonstrated for Harvey's direct traumas (OR = 3.18, 95% CI 1.85, 5.46), and COVID direct traumas (OR = 2.13, 95% CI 1.20, 3.77), and to a lesser extent for Harvey's indirect trauma (OR = 1.91, 95% CI 1.05, 3.46), as presented in [Table 2](#). The point estimates are higher for direct compared to indirect trauma, although the confidence intervals overlap. The full models are presented in [S2 Table](#). Estimates from the unadjusted models are presented in [S3 Table](#).

[Table 3](#) shows the OR for PTSD for cumulative exposure to the indirect traumas of Harvey and COVID (OR = 2.79, 95% CI 1.47, 5.28) and cumulative exposure to the direct traumas of these events (OR = 2.53, 95% CI 1.36, 4.70). The full models are presented in [S4 Table](#). Data from the unadjusted model can be found in [S5 Table](#).

Discussion

Our study demonstrates associations between exposure to both direct and indirect traumas resulting from large scale potentially traumatic events and the development of PTSD. Further, our data establishes associations between cumulative exposures to different large scale potentially traumatic events and the occurrence of PTSD.

In our study, approximately one out of eight participants (12.6%) fulfilled the criteria for current PTSD, three years after Hurricane Harvey and during the COVID pandemic. These data align with other studies examining PTSD among persons exposed to traumatic events using DSM criteria [4]. Additionally, our findings are consistent with other studies investigating the long-term consequences of natural disasters that occurred years earlier. For example, Raker et al. reported a 16.7% rate of post-traumatic symptoms in communities exposed to Hurricane Katrina 12 years after the event [46]. In a longitudinal study conducted by Goenjian et al., a PTSD rate of 11.6%, as per DSM-5 criteria, was identified among survivors of the Spitak earthquake in Armenia, 23 years after the incident [47]. Horesh et al. revealed a 16.5% rate of PTSD among veterans from Israel 20 years after experiencing the Lebanon war [48].

We showed an association between exposure to both direct and indirect traumas and PTSD. This finding supports the notion, consistent with other studies, that the inclusion of exposure to indirect trauma in the DSM-5 criteria was warranted. May and Wisco's review

suggests that indirect exposure to trauma among close associates, aligning with the definition used in our study, may lead to PTSD, albeit with a lower likelihood compared to direct exposure [49]. Solomon and Zerach's analysis of indirect exposures to trauma among family members of former Israeli prisoners of war who were exposed to war trauma and subsequently developed PTSD, provides evidence of the development of secondary traumatization among spouses and offspring [50]. Common mechanisms for both direct and indirect trauma are also evident in the study by Ten Holt et al., which found associations between both direct and indirect exposure to trauma and PTSD among patients with substance use disorder [12].

Our observation that persons directly affected by traumatic events consistently exhibited a higher prevalence of PTSD compared to those indirectly affected aligns with current literature, underscoring the intensity of event exposure as a significant risk factor for PTSD. Galea et al. demonstrated the impact of indirect exposure to the September 11 terror attacks on New York residents in relation to the development of PTSD, albeit to a lesser extent compared to individuals directly affected by the attacks [13]. In contrast, Kar et al. found no significant difference in PTSD prevalence among people directly or indirectly exposed to the 2004 Asian Tsunami disaster. However, their study defined indirect exposure as being in close proximity to the sea and witnessing all the devastation and trauma around, without specifying indirect exposure through affected loved ones [14].

Findings regarding the influence of indirect exposure to trauma on the development of PTSD are not conclusive in the literature. Merdjanhoff et al. found that indirect exposure to Hurricane Katrina at the community level was notably linked to psychological distress but did not show a significant association with probable PTSD [51]. However, this study did not define indirect exposure in alignment with the DSM PTSD criteria. Instead, it included stressors in the indirect exposure category, such as economic loss and lost income. Further, some studies have identified distinct features associated with direct and indirect exposure to traumas. For example, Christou-Ergos et al. demonstrated in Australia that individuals who directly experienced significant human suffering were less inclined to accept the COVID vaccine during the pandemic, whereas those with an indirect exposure to severe suffering showed a higher willingness to receive the vaccine [52].

Our study demonstrates a cumulative effect of exposure to multiple traumas on the development of PTSD. These findings are consistent with other studies that have explored the impact of exposure to multiple traumatic events. Schock et al. observed such a cumulative effect among refugees in Germany who had been exposed to various traumatic events [23]. Lowe et al. identified a cumulative effect of exposure to two disasters in the United States, namely Hurricane Katrina and the Deepwater Horizon oil spill [53]. Harville et al. showed that exposure to multiple hurricanes among United States Gulf Coast residents increased the risk of mental health issues, including PTSD [54]. Yehuda et al. found that Holocaust survivors with PTSD had experienced significantly more traumas in life compared to survivors without PTSD [55]. These findings are also in line with other studies that have examined the combined effects of COVID-19 and natural disasters, such as the work of Agyapong et al., which revealed a higher likelihood of PTSD and other mental health disorders among people in Canada who had experienced both COVID-19 and traumas like floods or wildfires [56].

We demonstrated a cumulative effect of indirect traumas on the risk of PTSD. Such effect is supported by other studies that have investigated the cumulative mechanisms of indirect trauma exposures. Fernandez et al. discovered that patients exposed to various disaster-related experiences in the New York area in 2001, including the World Trade Center disaster and the Flight 587 crash two months later, had poorer health status compared to those exposed to only one disaster. This also involved indirect experiences related to the deaths of friends and family in these events [57]. Garfin et al. found that prior indirect exposure to three community

traumas in the northern United States through the media increased the likelihood of citizens in the Boston and New York areas reacting more negatively to the Boston Marathon Bombing, which was a subsequent community trauma [58].

Limitations

Our study has several limitations. First, the analysis for HTRS findings does not include individuals who were residing outside of Houston during the hurricane. Second, the study had a relatively low response rate of 11.4%. However, this response rate is typical for community surveys that do not offer substantial compensation to respondents [59], and despite the response rate, adjustments were made for unit non-response using a weighting approach. Third, the study is cross-sectional in nature, and therefore cannot establish causal effects. However, the odds ratio analysis provides insights into the impact of exposures to direct and indirect trauma on PTSD. Fourth, the scales utilized to assess PTSD in our study are self-report measures and not clinical diagnoses. However, we employed the PTSD Checklist for DSM-5, along with rigorous algorithm [45], to identify probable cases of current PTSD. Fifth, several other social components besides traumatic exposure may contribute to the development of PTSD, which haven't been included in our analysis. These factors may include pre-existing mental conditions, such as acute stress disorder, anxiety sensitivity or baseline pain. However, our study focuses on traumatic events, which are the core experiences influencing the development of PTSD. And sixth, the questionnaire documents PTSD symptoms experienced during Hurricane Harvey. However, these symptoms may have originated earlier and may have been exacerbated by or reemerged in the context of the hurricane. This aligns with our interest in documenting the overall burden of PTSD following the Hurricane.

Implications

Despite these limitations, our findings underscore the need for further investigation into the particular trauma attributes that contribute to the onset of PTSD. They highlight the necessity for a comprehensive exploration of the mechanisms connecting both direct and indirect exposures to trauma, as well as the cumulative impact of multiple traumas on the manifestation of PTSD symptoms. Additionally, our findings support the incorporation of a cumulative effect, which is currently absent from the DSM's PTSD criteria.

Our results emphasize the importance of screening individuals affected by disasters for prior exposures to traumas, as well as screening those indirectly exposed to traumatic events, as both groups are at risk for the development of PTSD.

Further, our findings have implications for planning PTSD services, underscoring the need to develop specific programs targeting individuals exposed to indirect traumas, as well as those exposed to cumulative traumas, as vulnerable populations at risk of developing PTSD. These recommendations are particularly important in a time of compounding disasters and broad population exposures to these events [4, 60], and in light of studies that have identified other implications of trauma exposure, including psychiatric conditions like depression [61] and physical illnesses such as cardiovascular diseases [62].

The introduction of intervention programs for those exposed to cumulative traumas receives further support from studies revealing consequences for such exposures beyond PTSD. For example, Ruglass et al. found that cumulative exposure to traumatic events among American minority women increased the odds of being arrested due to criminal involvement [63]. This is particularly important given the emerging discussion in the scientific literature regarding efforts to proactively screen populations at risk for PTSD, driven by advancing research on preventive measures for the disorder [64].

Conclusions

Our study provides compelling evidence supporting the links between exposure to both direct and indirect traumas resulting from disasters and the onset of PTSD. Additionally, it firmly echoes evidence supporting relationships between cumulative exposures to various disasters and the emergence of PTSD [27–32].

The findings concerning the influence of cumulative exposure to indirect traumas on PTSD underscore the vital role of indirect experiences in the development of PTSD. This highlights the importance of screening individuals who have been indirectly exposed to traumas involving family members or loved ones, and further emphasizes the necessity of creating intervention programs customized for these individuals.

Supporting information

S1 Table. Trauma subvariables, prevalence and median split.

(DOCX)

S2 Table. Associations between types of direct and indirect trauma and PTSD, unadjusted.

(DOCX)

S3 Table. Associations between cumulative direct and indirect trauma and PTSD, unadjusted.

(DOCX)

S4 Table. Associations between cumulative direct and indirect trauma and PTSD.

(DOCX)

S5 Table. Associations between cumulative direct and indirect trauma and PTSD, unadjusted.

(DOCX)

Author Contributions

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