Did internal displacement from the 2010 earthquake in Haiti lead to long-term violence against children? A matched pairs study design

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Abstract

Background

Empirical evidence is limited and contradictory on violence against children after internal displacement from natural disasters. Understanding how internal displacement affects violence is key in structuring effective prevention and response.

Objective

We examined the effect of internal displacement from the 2010 Haitian earthquake on long-term physical, emotional, and sexual violence against children and outlined a methodological framework to improve future evidence quality.

Participants and setting

We analyzed violence against adolescent girls and boys within the nationally representative, Haiti Violence Against Children Survey.

Methods

We pre-processed data by matching on pre-earthquake characteristics for displaced and non-displaced children and applied 95% confidence intervals from McNemar's exact test, with

sensitivity analyses, to evaluate differences in violence outcomes between matched pairs after the earthquake.

Results

Internal displacement was not associated with past 12-month physical, emotional, and sexual violence two years after the earthquake for girls and boys. Most violence outcomes were robust to potential unmeasured confounding. Odds ratios for any form of violence against girls were 0.84 (95% CI: 0.52-1.33, $p = 0.500$) and against boys were 1.03 (95% CI: 0.61-1.73, $p = 1.000$).

Conclusions

Internal displacement was not a driver of long-term violence against children in Haiti. Current global protocols in disaster settings may initiate services after the optimal window of time to protect children from violence, and the post-displacement setting may be central in determining violence outcomes. The combination of specific data structures and matching methodologies is promising to increase evidence quality after rapid-onset natural disasters, especially in low-resource settings.

Keywords

Natural disaster; internal displacement; humanitarian emergency; Haiti; violence

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Introduction

On January 12, 2010 Haiti experienced a 7.0 magnitude earthquake near the capital city of Port-au-Prince (Doocy, Cherewick, & Kirsch, 2013). Port-au-Prince lost an estimated 23% of its population from internal displacement to camps, informal settlements, and other regions of the country (Lu, Bengtsson, & Holme, 2012). International humanitarian aid was substantial, surpassing US$9 billion, but the loss of infrastructure and high death toll among members of the Haitian government and the United Nations fractured coordination (Kirsch, Sauer, & Guha Sapir, 2012; Ramachandran & Walz, 2015). Several evaluations highlighted that the provision of services was insufficient to protect and respond to violence against internally displaced persons, or IDPs, in both communities and camp settings (Center for Human Rights and Global Justice, 2012; The Interuniversity Institute for Research and Development, 2010). Prior studies have reported widespread criminality and sexual violence against women and girls committed by criminal gangs and armed men in the immediate aftermath of the earthquake and months and years that followed (Amnesty International, 2011; Kolbe et al., 2010). A study that isolated effect of the Haitian earthquake on the probability of intimate partner violence among adult women nationally found that physical violence increased in the most devastated areas of the country and decreased in minimally affected areas. The probability of sexual violence likewise differed, decreasing by over 300 percent in moderately affected areas as opposed to devasted regions. Both physical and sexual violence importantly were higher among women in IDP camps than the general population but not significant different among women who were displaced by the earthquake (Weitzman & Behrman, 2016). It remains uncertain how earthquake exposure and internal displacement was associated with violence against children within affected households and caregiving networks.

The pathways between natural disasters and violence against children are highly complex and indirect. Population movement is often inherently part of natural disaster exposure. As Rashid and Michaud (2000) highlight in their interviews with flood-affected communities in Bangladesh, girls attributed new cases of sexual violence to the influx of unknown young men—some affiliated with criminal groups—into their neighborhoods. Large-scale displacement into communities poses security risks, especially when coupled with a breakdown of social systems of protection and policing, common in disaster events. Predatory acts of sexual violence moreover can occur when children are displaced to new environments, such as IDP camps or informal settlements. Camps and informal settlements are often overcrowded transitional spaces that lack security in terms of policing, secure housing and private living spaces, and lighting (Davis & Bookey, 2011; Standing, Parker, & Bista, 2016).

Natural disasters and internal displacement lead to changes in the family system. Caregivers may be physically separated from their children or die during or after a natural disaster. A lack of supervision makes children vulnerable to violence but also threatens their overall wellbeing, which elevates future violence risk (Cas, Frankenberg, Suriastini, & Thomas, 2014). Natural disasters and internal displacement increase economic hardship, especially for low-income families (Miljkovic & Miljkovic, 2014). New financial strains may cause caregivers to migrate to different areas for work opportunities, leaving their children in the care of others or unaccompanied. Particularly girls may travel independently over great distances to collect firewood or water, which is a known risk for sexual violence (Spangaro et al., 2013). Children further may be forced to work to support their families and face new threats of violence and exploitation from their employers.

Social support to families often is reduced, given the strain on social networks that similarly may have experienced the natural disaster or increases in distance after displacement to separate regions (Morris & Deterding, 2016).

Natural disasters and internal displacement cause extreme upheaval that psychologically can affect individuals. Mental distress and psychopathology among caregivers and affected community members is common and may produce increases in violence against children (Biswas, Rahman, Mashreky, Rahman, & Dalal, 2010; Neria, Nandi, & Galea, 2008). Negative coping behaviors, such as hazardous alcohol usage, often increase after natural disasters, which present an additional risk factor for violence. After the 2004 Indian Ocean tsunami, for instance, alcohol usage by Sri Lankan fathers was significantly associated with physical, emotional, and sexual violence (β = 0.16, r_{bp} = 0.18, $p < 0.01$) (Catani, Jacob, Schauer, Kohila, & Neuner, 2008). Economic hardship further leads to caregiver stress, resulting in harsh acts of physical or emotional violence (Biswas et al., 2010).

Children who are internally displaced are particularly vulnerable to experiencing violence, because they remain in unstable settings within their countries of origin, and within families and communities that experience disproportionate levels of distress during natural disasters and displacement. A global meta-analysis of 56 mental health studies confirmed that IDPs tend to have higher levels of psychopathology than refugees who left their country of origin (Q = 65.47, R^2 = 0.05, $p < 0.001$) (Porter & Haslam, 2005). Specific to Haiti, the prevalence estimates for posttraumatic stress disorder (PTSD) and major depressive disorder two to four months after the

earthquake were 29.7% and 28.8% for IDPs, as compared to 19.1% and 21.9% for the general population in Port-au-Prince ($p < 0.01$) (Cerdá et al., 2013).

Eliminating violence against children is a global commitment outlined in Sustainable Development Goal (SDG) 16.2 and a public health priority of the World Health Organization (United Nations General Assembly, 2015; World Health Assembly, 1996). Violence prevention and response in humanitarian emergencies—caused by natural disasters, war, and mass population movement—is key in achieving this goal. The United Nations Office for the Coordination of Humanitarian Affairs (OCHA) estimated that more than 1% of the world's population was affected by a humanitarian emergency in 2017 (United Nations Office for the Coordination of Humanitarian Affairs, 2019). Between 2008 and 2016, natural disasters displaced an average 25.3 million people per year, with the largest proportion of people displaced within the borders of their home country (International Displacement Monitoring Centre, 2017). These numbers are projected to increase in the future, due to uneven population growth in the most affected areas and the increasing effect of climate change on humanity (Peduzzi, Dao, Herold, & Mouton, 2009). Children are overrepresented in humanitarian emergencies, representing 48 million of those who required assistance in 2017 (United Nations Children's Fund, 2018). Most evidence that documents the relationship between widescale catastrophic events and violence against children, however, comes from situations of armed conflict, and less is known about possible differences in violence patterns after exposure and displacement from natural disasters (Catani et al., 2010; Catani, Schauer, & Neuner, 2008; Rubenstein, Lu, MacFarlane, & Stark, 2017; Stark, Warner, Lehmann, Boothby, & Ager, 2013).

Numerous methodological challenges exist in measurement of violence after natural disasters and internal displacement. Prediction of the exact location and occurrence of natural disasters is difficult (Gerstenberger, Wiemer, Jones, & Reasenberg, 2005; Titov et al., 2005). Studies commonly rely on the chance existence of prior data collection with the affected population and less commonly, on a cross-sectional survey afterwards (Chen, Halliday, & Fan, 2016; Kolbe et al., 2010). The former is inconsistently available, and the latter suffers from a lack of temporality in understanding cause and effect, as correlations do not necessarily imply causation (Aldrich, 1995). Observational studies used to study violence after population-based displacement events typically face threats to validity because of confounding. The isolation of effect is complicated by an array of social, economic, and behavioral factors that are correlated with violence outcomes (Doidge, Higgins, Delfabbro, & Segal, 2017; Dong et al., 2004; Maguire-Jack & Font, 2017). Internal displacement is usually influenced by having a lack of economic means, as the poorest of the poor are both more likely to be displaced within their own country and spatially concentrate in remote areas where instability and economic or environmental shocks frequently lead to displacement (Cohen & Deng, 1998). In contrast, rapid-onset natural disasters like the Haitian earthquake act as natural experiments in that for a brief moment, they quasi-randomly assign a large segment of the population to internal displacement (Zubizarreta, Small, & Rosenbaum, 2014). The resulting estimates are less influenced by other factors that would typically confound observational studies (Zubizarreta, Cerdá, & Rosenbaum, 2013).

This study aims to analyze the effect of internal displacement from the Haitian earthquake on long-term physical, emotional, and sexual violence against girls and boys. It secondarily lays out a

framework for certain data structures and analysis techniques to establish an empirical evidence base for violence against children after rapid-onset natural disasters.

Methods

We used matching methods to pair individuals within exposed (displaced) and comparison groups (non-displaced) who were similar on all observed pre-earthquake covariates within a nationally representative cross-sectional survey for Haiti. We subsequently evaluated the relationship between internal displacement from the earthquake and physical, emotional, and sexual violence that occurred after the earthquake by gender. Our estimate of internal displacement from the earthquake targeted the average treatment effect on the treated (ATT), which constitutes the potential difference in violence outcomes for displaced people if they had not been displaced. The matching procedure was designed to find suitable individuals in the comparison group who would have survived the earthquake and not had the economic means or social connections to move outside of the country.

INSERT FIGURE 1

Data source

The Haitian Violence Against Children Survey (VACS) is a nationally representative household survey administered in Haitian Kreyol in 2012—two years following the Haitian earthquake. Sampling methods stratified girls and boys into different clusters, providing representative estimates by gender and a sample of IDPs in communities and camp settings. In total, 1,457 girls and 1,459 boys completed the survey, with individual response rates of 93.1% for girls and 88.5%

for boys. Data collectors obtained informed consent from caregivers and assent from the child respondents. The data collection methods and protocols are described in greater detail in the VACS final report (Centers for Disease Control and Prevention, Interuniversity Institute for Research and Development, & Comité de Coordination, 2014).

Variable description

The binary exposure variable was captured by asking respondents if they had moved or changed households as a result of the earthquake. Earthquake exposure is decomposed into one element—internal displacement to any location, including both camps and communities. Binary violence outcomes were measured as experiences in the past 12 months. Since the survey was conducted from April-June 2012, these violence outcomes had to occur after the earthquake. As per the conventions of the VACS, the forms of violence were: (1) physical violence from parents, caregivers, adult relatives, or other adult household members; (2) physical violence from authority figures in the community; (3) emotional violence from parents, caregivers, adult relatives, or other adult household members; and (4) sexual violence from anyone (see Supplementary File 1) (Centers for Disease Control and Prevention et al., 2014).

We constructed pre-earthquake covariates for matching the exposed and comparison groups. Limiting to pre-earthquake covariates importantly reduced the potential that measured characteristics used in matching were derived from experiences during or after the earthquake. We selected covariates in the survey that most strongly would confound the association between earthquake exposure and violence against children and constructed dummy variables by subtracting the respondent's current age at the date of the survey with the age of occurrence. A

timeframe of three or more years was deemed as occurring before the earthquake. We specifically constructed covariates on experiences of physical, emotional, and sexual violence before the earthquake to minimize possible confounding from past events (see Supplementary File 2).

Study design and matching

We restricted our analysis to the sample of 13 to 17 years old girls (n = 635) and boys (n = 758) in each survey. As part of our study design, we assessed whether or not we had sufficient statistical power to reliably detect the size of effects that we anticipated in our analysis (see Supplementary Files 3-5). Data were pre-processed using the propensity score to trim individuals outside of the area of common support—the area of overlap in which the exposed group has candidate counterfactuals for matching (Rosenbaum, 2010).

We considered matching methods within the trimmed dataset to minimize the standardized mean difference (SMD) of the pre-earthquake covariates between exposed and comparison groups, blinding ourselves to violence outcomes until after settling on a particular matching design. We prioritized matches that yielded a SMD within the range of +/- 0.10 (10 percent) (see Supplementary File 6) (Normand et al., 2001). In recognizing the importance of certain covariates in violence occurrence, we additionally prioritized the matching method that most reduced SMD for pre-earthquake sexual violence for girls and physical violence in households for boys. We chose these covariates, because they have been shown to be prevalent gendered forms of violence in past studies (Stoltenborgh, van IJzendoorn, Euser, & Bakermans-Kranenburg, 2011), were highlighted as most important for girls and boys in Haiti during a qualitative pre-study of the VACS (Centers for Disease Control and Prevention & Interuniversity Institute for Research and

Development, 2011), and would likely be the most predictive of subsequent violence following the earthquake. Using the outlined balance criteria, we selected a 1:1 Euclidean distance match with a 0.2 caliper for both girls and boys. We implemented optimal matching using the `optmatch` package (Hansen & Klopfer, 2006).

INSERT FIGURES 2 & 3

We used decision trees to articulate the implicit exclusion criteria that came about from trimming and optimally matching, which is analogous to describing inclusion and exclusion criteria in a randomized controlled trial (see Supplementary Files 7-8) (Traskin & Small, 2011).

Statistical analysis

We evaluated 95% confidence intervals (CI) from McNemar's exact test for matched pairs to determine differences in violence outcomes after internal displacement from the earthquake and considered *p*-values of less than 0.05 significant. In addition, we applied a multivariate analysis of covariance (MANCOVA) with a Pillai test to explore patterns of violence. Differences in patterns of missingness between exposed and comparison groups were assessed by using chained Fisher's exact tests. We conducted gamma sensitivity analysis to determine the potential for unobserved confounders to alter our observed results (Rosenbaum, 2010). We additionally ran power calculations to determine if the sample size of the matched pairs was sufficient to detect changes in violence after the earthquake, based upon pre-earthquake estimates of violence in Haiti. The data were cleaned in Stata 15 and matched and analyzed in R v.3.3.3 (R Core Team, 2017; StataCorp, 2017).

Results

Description of the study population

The majority of children living in camps in the study population were displaced by the Haitian earthquake. As is the case for most IDPs globally, a sizable percentage of displaced children lived outside of camps at the time of the survey (girls: 21.9% and boys: 20.8%) (United Nations & European Union, 2018). Approximately half of girls (46.9%) and boys (54.1%) within the original sample experienced some form of violence before the earthquake. The absolute number of violent experiences by gender was similar after internal displacement from the earthquake (girls: 52.6% and boys: 47.4%). The matched pairs mirrored the original sample, exhibiting high levels of violence before and after the earthquake among girls and boys.

284 Table 1. Prevalence of violence before and after the Haitian earthquake in the matched pairs of girls and boys

	Girls				Boys			
	Before		After		Before		After	
Violence Type	**Estimate (n)**	**Percentage (%)**	**Estimate (n)**	**Percentage (%)**	**Estimate (n)**	**Percentage (%)**	**Estimate (n)**	**Percentage (%)**
Physical violence from adults in household	120	39.2%	109	35.6%	151	43.9%	100	29.1%
Physical violence from authority figures	34	11.1%	41	13.4%	36	10.5%	59	17.2%

Emotional violence from adults in household	52	17.0%	94	30.7%	62	18.0%	62	18.0%
Sexual violence from anyone	31	10.1%	65	21.2%	24	7.0%	34	9.9%
Any form of violence	151	49.3%	172	56.2%	182	52.9%	157	45.6%

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Results of study design

The matching yielded 153 pairs of girls and 172 pairs of boys (see Supplementary Files 9-10). Our analysis was sufficiently powered to detect changes comparable to Demographic Health Survey (DHS) estimates on national violence prevalence in Haiti before the earthquake (Cohen's $h = 0.20$) (Cayemittes, Placide, Barrère, Mariko, & Sévère, 2001; Cayemittes et al., 2007).

Violence against girls after internal displacement

The odds ratios associating internal displacement from the earthquake with long-term physical, emotional, or sexual violence were near null for girls. Multivariate analysis combining violence outcomes followed a similar pattern, with no appreciable difference between exposed and comparison groups ($F = 2.11$, $df = 4, 294$, $p = 0.080$). The exposed and comparison groups did not have substantial differences in their patterns of missingness for any form of violence. Sensitivity analysis showed that sexual violence outcomes were highly sensitive to possible bias from unmeasured confounding (the presence of $\Gamma = 1.1$ magnitude of bias could give rise to a connection between internal displacement and violence; $p = 0.048$) (see Supplementary File 11, Table S6).

Violence against boys after internal displacement

The odds ratios associating internal displacement from the earthquake with long-term physical, emotional, or sexual violence were similarly near null for boys. As in the case of girls, multivariate analysis did not exhibit a different pattern in violence outcomes when combined ($F = 0.98$, $df = 4, 324$, $p = 0.417$). The exposed and comparison groups likewise did not show evidence of differences in their patterns of missingness. Sensitivity analysis illustrated that physical violence perpetrated by authority figures was moderately sensitive to possible bias from unmeasured confounding (the

presence of Γ = 1.2 magnitude of bias could give rise to a connection between internal displacement and violence; p = 0.045) (see Supplementary File 11, Table S7).

Table 2. Differences in violence outcomes after the Haitian earthquake for displaced and non-displaced girls and boys

	Girls			Boys		
Violence Type	**Estimate**	**95% CI**	***p*-value**	**Estimate**	**95% CI**	***p*-value**
Physical violence by adults in household	0.90	0.52-1.56	0.795	1.35	0.83-2.23	0.242
Physical violence by authority figures	1.67	0.85-3.40	0.154	0.87	0.38-1.95	0.851
Emotional violence by adults in household	1.11	0.57-2.17	0.875	1.39	0.79-2.49	0.281
Sexual violence by anyone	1.29	0.60-2.79	0.597	0.57	0.29-1.09	0.096
Any form of violence	0.84	0.52-1.33	0.500	1.03	0.61-1.73	1.000

Estimate = odds ratio; rounded to two decimal places

Discussion

We found that internal displacement was not associated with past-12 month physical, emotional, or sexual violence against girls or boys within affected households and caregiving networks two years after the earthquake in Haiti. Our findings present a hopeful picture that internal

displacement from the earthquake was not a driving factor of long-term violence against children in Haitian society. The VACS sampling structure and our implicit inclusion criteria suggest that we are able to generalize to all Haitian children who would have been internally displaced by the earthquake and who did not have the economic means or social connections to move elsewhere. The results therefore provide representative estimates for the affected population of children that remained in Haiti after the earthquake. Sensitivity analysis indicates that the results are resistant to high levels of possible unobserved biases, with the exception of sexual violence against girls and physical violence perpetrated by authority figures against boys. We can have confidence in the majority of our findings, but we must interpret the results for these two gendered forms of violence with caution in light of the prospect that bias exists and was not measured in the survey.

Prior studies that investigate violence against children after disaster and displacement exposure have had mixed findings. A recent meta-analysis found that natural disasters were not associated with physical, emotional, and sexual violence against children (Cerna-Turoff, Fischer, Mayhew, & Devries, 2019). Specific analyses that isolated the mediated effect of internal displacement as distinct from natural disaster exposure were noticeably absent. The most relevant included study on Hurricane Ike in the United States concluded that boys who were not evacuated were more likely to perpetrate physical dating violence (aOR 3.19, 95% CI 1.50-6.80, $p < 0.01$) and perpetrate or be victims of sexual violence (perpetration: aOR 3.73, 95% CI 1.50-9.28, $p < 0.01$; victimization: aOR 2.47, 95% CI 1.17-5.23, $p < 0.05$) (Temple et al., 2011). Among adult women, residing in an IDP camp increased the probability of physical and sexual violence but not general displacement due to property destruction or loss from the Haitian earthquake (Weitzman & Behrman, 2016).

Temporal trends are similarly unclear. Two studies from the United States point to an initial increase in the first six months after several natural disasters, which decreases over time (Curtis, Miller, & Berry, 2000; Keenan, Marshall, Nocera, & Runyan, 2004). Kolbe (2010) identified a large number of new cases of sexual violence against girls in Port-au-Prince in the six weeks after the Haitian earthquake, and Weitzman and Behrman (2016) found that the probability of physical and sexual intimate partner violence increased among adult Haitian women in the two years following the earthquake. In contrast, a study on physical, emotional, and sexual violence against internally displaced girls in camps one to three years after the earthquake in Haiti found no association, although the study faced several methodological challenges arising from limited sample sizes ($N = 78$) and incomplete use of validated violence scales for measurement (Sloand et al., 2017). The 2012 DHS similarly found a lower prevalence of physical and sexual intimate partner violence against internally displaced adolescent girls in camps than the general population after the earthquake (Cayemittes et al., 2013).

Limitations and strengths

Our findings must be considered in conjunction with the study's limitations. We did not have in-depth information to decompose earthquake exposure into other distinct elements and test their effect on violence. Ideally, we would have had access to the subgroup of people who had been displaced to a camp or informal settlement but currently resided in the wider community. The CDC's initial analysis reported that Haitian girls and young women who lived in the camps at the time of the survey had a higher probability of experiencing post-earthquake sexual violence (Centers for Disease Control and Prevention & Interuniversity Institute for Research and

366 Development, 2011). Their analysis did not adjust for pre-earthquake violence, measure the effect
367 of displacement on violence, or compare the estimates with the population of IDPs who no longer
368 lived in camps. A related limitation is that we did not have a measure of earthquake intensity that
369 could have been used to partition exposure into any unexplained deviation from randomness.
370 While an instrumental variable analysis would have offered an additional mechanism to reduce
371 possible biases in exposure, displacement as a clear binary question is less sensitive to unmeasured
372 biases than incremental changes in earthquake intensity (Rosenbaum, 2004). This point may be
373 salient in terms of a related national study on intimate partner violence against adult women in
374 Haiti, which used three gradations of earthquake intensity to determine exposure (Weitzman &
375 Behrman, 2016).
376
377 We could not include certain covariates in the matching metric that are typically associated with
378 violence in other settings, namely pre-earthquake place of residence and socio-economic status
379 (Willman & Marcelin, 2010). Geographic residence in where the children lived before the
380 earthquake may have biased this study's conclusions towards the null. Available data indicates
381 that Port-au-Prince had a lower corporal punishment prevalence than in rural or other urban areas
382 of Haiti before the earthquake (Cayemittes et al., 2001). In contrast, poverty would have biased
383 away from the null in this sample, given that poverty is a risk factor for violence (Maguire-Jack &
384 Font, 2017). The temporary and powerful mass disruption of the Haitian earthquake on the
385 population-level likely helped to reduce both of their influences in this analysis (Zubizarreta et al.,
386 2014).
387

We likewise did not have sufficient information to match on frequency and severity of violence before the earthquake or protective factors. Overall characteristics for girls and boys who experienced violence once may differ from those who frequently experience violence. Matching methods, however, are not meant to pinpoint the exact same type of person for each characteristic but rather, to construct "profiles of risk" for similar people across exposed and comparison groups (Rosenbaum & Rubin, 1983). We additionally were able to determine that no child was in a marriage-like relationship before the earthquake, reducing the possibility of ongoing intimate partner violence. Certain groups in Haiti may be resilient to the stress-trauma pathway and exhibit low rates of violence against children after a large-scale disaster and internal displacement. In other contexts, people who reported high social cohesion and a lack of racial discrimination before Hurricane Katrina and high social capital before a natural disaster in Japan had lower trauma responses (Tsuchiya et al., 2017; Weems et al., 2007). These covariates and other possibly relevant characteristics were not measured in the VACS, which has the potential to bias estimates. We tested the strength of our findings in sensitivity analysis for this reason. Apart from physical violence committed by authority figures against boys and sexual violence against girls, a high amount of possible bias introduced by unobserved confounders would be needed to change our study results.

We could not track short-term temporal changes in violence after the earthquake. Data collection for the Haiti VACS was conducted 14 to 16 months after the earthquake. The violence measures were assessed for the time period of 12 months before the survey (Centers for Disease Control and Prevention et al., 2014). Therefore, the immediate two to four months following the earthquake were not included in this analysis. Violence may have increased in the initial aftermath of the

earthquake, but this study was designed to understand violence sustained over a different timescale.

The current study is not well-designed to identify issues arising from spillover effects which violate the Stable Unit Treatment Value Assumption (SUTVA). An example would be if the influx of internally displaced children to a non-earthquake region increased the rates of violence against non-displaced girls and boys. This possibility would tend to bias the current study design toward finding false null results. Spillover effects are quite likely in rapid-onset natural disasters but require measurement of spillover pathways not collected in this survey and sophisticated methods that to our knowledge have not been implemented in population-based surveys in humanitarian emergencies.

This study had multiple strengths notwithstanding its limitations. We had access to a nationally representative survey that extensively measured physical, emotional, and sexual violence against children, with the appropriate data structure to create pre-earthquake covariates and identify long-term gendered effects. We then applied an experimental approach to reduce potential biases. The sample size used for our analysis was sufficiently powered to detect small changes in violence outcomes (Cohen's $h = 0.20$). The survey question linked to the exposure variable—self-reported internal displacement because of the earthquake—was not likely affected by recall bias among the sampled children. Most IDPs in Haiti furthermore remained in country after the earthquake (Bengtsson, Lu, Thorson, Garfield, & von Schreeb, 2011). Statistical analysis did not indicate that missingness in children's response patterns was likely to change our findings. In addition, the discarded observations from the comparison group did not appear to contain an important

subpopulation of children who were at elevated risk for violence. Multivariate analysis further did not find that physical, emotional, and sexual violence covaried, which suggests that internal displacement did not act in a joint manner on violence outcomes, apart from each individual effect.

Conclusions and future implications

This study contributes to increased knowledge of violence within disaster- and displacement-affected populations and can inform policies and service provision towards global priorities to end violence against children. Current global operating protocols in emergencies call for initiation of violence prevention and response services months after the disaster event and displacement, based upon a theory of sustained increases in violence (Inter-Agency Standing Committee, 2006). In settings with "acute on chronic" underdevelopment and repeat episodic natural disasters, like Haiti, the affected population may possess a high-level of resilience to recover from traumatic experiences quickly (Gabrielli & Gill, 2014). We may be missing the optimal window of time to respond to disaster and displacement exposure with targeted interventions to protect children.

The experience of internal displacement on the population level may be less important in determining long-term violence outcomes than the location of displacement. Internal displacement to a camp or informal settlement particularly may exacerbate risk, as indicated in a study of the impact of the Haitian earthquake on violence against adult women (Weitzman & Behrman, 2016). Better documentation of changes in violence over time, protective factors, subgroup differences, and other aspects of the exposure and displacement experience would provide a more nuanced understanding of violence patterns among children. Further study is merited specifically on sexual violence against girls and physical violence perpetrated by authority figures against boys due to

their sensitivity to potential unmeasured biases. Moreover, internal displacement due to natural disasters may affect populations differently than other humanitarian emergencies, such as armed conflict, and violence patterns may diverge as a result (Catani, Jacob, et al., 2008; Norris et al., 2002; Rubenstein et al., 2017). Data collection that can account for pre-disaster characteristics would aid in confirming if these dynamics are consistent across disaster settings and in countries that experience overlapping cycles of man-made violence and political instability (Hallward, 2010).

Natural disasters are often unpredictable events and therefore, present challenges in designing studies which include a baseline when one does not know when an event will occur and who will be affected (Gerstenberger et al., 2005; Titov et al., 2005). The analysis of a single, representative cross-sectional survey of the affected and unaffected population is logistically more feasible than pre-post studies, given the costs and time required to trace the affected population. This approach is especially relevant to low- and middle-income settings where infrastructure and surveillance systems are incomplete or weak (Galea, Maxwell, & Norris, 2008). Rapid-onset natural disasters are specifically suited for this method, because they act as population randomizers, and unlike armed conflict, may exhibit less strong spatial patterns (Guo, Lu, Doñate, & Johnson, 2017). By creating pre-earthquake covariates and analyzing data with matching methods, we gained some of the benefits of pre-post design in a low-resource setting and reduced the confounding inherent in observational studies (Rubin, 2005).

Figure captions

Fig 1. Mapping of shake intensity by communes. Data source is the United States Geological Survey and map produced in the `Mapview` package (Appelhans, Detsch, Reudenbach, & Woellauer, 2018; United States Geological Survey, n.d.)

Fig 2. Love plot of pre-earthquake covariate balance before and after matching for girls

Fig 3. Love plot of pre-earthquake covariate balance before and after matching for boys

References

Aldrich, J. (1995). Correlations genuine and spurious in Pearson and Yule. *Statistical Science*, *10*(4), 364–376.

Amnesty International. (2011). *Aftershocks: women speak out against sexual violence in Haiti's camps*. London. Retrieved from https://www.amnesty.org/download/Documents/28000/amr360012011en.pdf

Appelhans, T., Detsch, F., Reudenbach, C., & Woellauer, S. (2018). *mapview: interactive viewing of spatial data in R*. Retrieved from https://cran.r-project.org/package=mapview

Bengtsson, L., Lu, X., Thorson, A., Garfield, R., & von Schreeb, J. (2011). Improved response to disasters and outbreaks by tracking population movements with mobile phone network data: a post-earthquake geospatial study in Haiti. *PLoS Medicine*, *8*(8), e1001083.

Biswas, A., Rahman, A., Mashreky, S., Rahman, F., & Dalal, K. (2010). Unintentional injuries and parental violence against children during flood: a study in rural Bangladesh. *Rural and Remote Health*, *10*(1), 1199.

Cas, A. G., Frankenberg, E., Suriastini, W., & Thomas, D. (2014). The impact of parental death on child well-being: evidence from the Indian Ocean Tsunami. *Demography*, *5*1(2), 437–457.

Catani, C., Gewirtz, A. H., Wieling, E., Schauer, E., Elbert, T., & Neuner, F. (2010). Tsunami, war, and cumulative risk in the lives of Sri Lankan schoolchildren. *Child Development*, *81*(4), 1176–1191.

Catani, C., Jacob, N., Schauer, E., Kohila, M., & Neuner, F. (2008). Family violence, war, and natural disasters: a study of the effect of extreme stress on children's mental health in Sri Lanka. *BMC Psychiatry*, *8*(33).

Catani, C., Schauer, E., & Neuner, F. (2008). Beyond individual war trauma: domestic violence against children in Afghanistan and Sri Lanka. *Journal of Marital and Family Therapy*, *34*(2), 165–176.

Cayemittes, M., Busangu, M. F., De Dieu Bizimana, J., Barrère, B., Sévère, B., Cayemittes, V., & Charles, E. (2013). *Enquête mortalité, morbidité et utilisation des services, Haïti, 2012*. Calverton, MD. Retrieved from http://www.measuredhs.com

Cayemittes, M., Placide, M. F., Barrère, B., Mariko, S., & Sévère, B. (2001). *Enquête mortalité, morbidité et utilisation des services, Haïti 2000*. Calverton, MD. Retrieved from https://dhsprogram.com/publications/publication-FR121-DHS-Final-Reports.cfm

Cayemittes, M., Placide, M. F., Mariko, S., Barrère, B., Sévère, B., & Alexandre, C. (2007). *Enquête mortalité, morbidité et utilisation des services, Haïti, 2005-2006*. Calverton, MD. Retrieved from https://dhsprogram.com/publications/publication-fr192-dhs-final-reports.cfm

Centers for Disease Control and Prevention, & Interuniversity Institute for Research and Development. (2011). *Violence against children survey (VACS) Haiti, report for the Comité de Coordination - focus groups to inform VACS Haiti*. Atlanta, GA. Retrieved from https://www.togetherforgirls.org/wp-content/uploads/2017/10/VACS-Haiti-Qualitative-

Report_FINAL.pdf

Centers for Disease Control and Prevention, Interuniversity Institute for Research and Development, & Comité de Coordination. (2014). *Violence against children in Haiti: findings from a national survey, 2012*. Port-au-Prince, Haiti. Retrieved from https://www.cdc.gov/violenceprevention/pdf/violence-haiti.pdf

Cerdá, M., Paczkowski, M., Galea, S., Nemethy, K., Péan, C., & Desvarieux, M. (2013). Psychopathology in the aftermath of the Haitian earthquake: a population-based study of posttraumatic stress disorder and major depression. *Depression and Anxiety*, *30*(5), 413–424.

Cerna-Turoff, I., Fischer, H.-T., Mayhew, S., & Devries, K. (2019). Violence against children and natural disasters: a systematic review and meta-analysis of quantitative evidence. *PLoS ONE*, *14*(5), e0217719.

Chen, B., Halliday, T. J., & Fan, V. Y. (2016). The impact of internal displacement on child mortality in post-earthquake Haiti: a difference-in-differences analysis. *International Journal for Equity in Health*, *15*(1), 114.

Cohen, R., & Deng, F. M. (Eds.). (1998). *Masses in flight: the global crisis of internal displacement* (1st edition). Washington, DC: Brookings Institution Press.

Curtis, T., Miller, B. C., & Berry, E. H. (2000). Changes in reports and incidence of child abuse following natural disasters. *Child Abuse & Neglect*, *24*(9), 1151–1162.

Davis, L., & Bookey, B. (2011). Fanm ayisyen pap kase: respecting the right to health of Haitian women and girls. *Health and Human Rights*, *13*(1), E50–E61.

Doidge, J. C., Higgins, D. J., Delfabbro, P., & Segal, L. (2017). Risk factors for child maltreatment in an Australian population-based birth cohort. *Child Abuse & Neglect*, *64*,

47–60.

Dong, M., Anda, R. F., Felitti, V. J., Dube, S. R., Williamson, D. F., Thompson, T. J., … Giles, W. H. (2004). The interrelatedness of multiple forms of childhood abuse, neglect, and household dysfunction. *Child Abuse & Neglect*, *28*(7), 771–784.

Doocy, S., Cherewick, M., & Kirsch, T. (2013). Mortality following the Haitian earthquake of 2010: a stratified cluster survey. *Population Health Metrics*, *11*(1), 5.

Gabrielli, J., & Gill, M. (2014). Psychological perspectives on "acute on chronic" trauma in children: implications of the 2010 earthquake in Haiti. *Children & Society*, *28*, 438–450.

Galea, S., Maxwell, A. R., & Norris, F. (2008). Sampling and design challenges in studying the mental health consequences of disasters. *International Journal of Methods in Psychiatric Research*, *17*(S2), 21–28.

Gerstenberger, M. C., Wiemer, S., Jones, L. M., & Reasenberg, P. A. (2005). Real-time forecasts of tomorrow's earthquakes in California. *Nature*, *435*(7040), 328–331.

Center for Human Rights and Global Justice. (2012). *Yon je louvri: reducing vulnerability to sexual violence in Haiti's IDP camps*. New York, NY. Retrieved from www.chrgj.org

Guo, W., Lu, X., Doñate, G. M., & Johnson, S. (2017). *The spatial ecology of war and peace*. Retrieved from https://arxiv.org/pdf/1604.01693.pdf

Hallward, P. (2010). *Damming the flood: Haiti and the politics of containment* (2nd ed.). Brooklyn, NY: Verso.

Hansen, B. B., & Klopfer, S. O. (2006). Optimal full matching and related designs via network flows. *Journal of Computational and Graphical Statistics*, *15*(3), 609–627.

Inter-Agency Standing Committee. (2006). *Guideline using the cluster approach to strengthen humanitarian response*. Retrieved from

https://interagencystandingcommittee.org/system/files/legacy_files/guidance_note_on_using_the_cluster_approach_to_strengthen_humanitarian_response.pdf

International Displacement Monitoring Centre. (2017). *Global report on internal displacement - GRID 2017*. Geneva, Switzerland. Retrieved from http://www.internal-displacement.org/global-report/grid2017/pdfs/2017-GRID.pdf

Interuniversity Institute for Research and Development. (2010). *Voices from the shanties: a post-earthquake rapid assessment of Cité Soleil, Port-au-Prince*. Port-au-Prince, Haiti. Retrieved from http://www.inured.org/uploads/2/5/2/6/25266591/voices_from_the_shanties.pdf

Keenan, H. T., Marshall, S. W., Nocera, M. A., & Runyan, D. K. (2004). Increased incidence of inflicted traumatic brain injury in children after a natural disaster. *American Journal of Preventive Medicine*, *26*(3), 189–193.

Kirsch, T., Sauer, L., & Guha Sapir, D. (2012). Analysis of the international and US response to the Haiti earthquake: recommendations for change. *Disaster Medicine and Public Health Preparedness*, *6*(3), 200–208.

Kolbe, A. R., Hutson, R. A., Shannon, H., Trzcinski, E., Miles, B., Levitz, N., … Muggah, R. (2010). Mortality, crime and access to basic needs before and after the Haiti earthquake: a random survey of Port-au-Prince households. *Medicine, Conflict and Survival*, *26*(4), 281–297.

Lu, X., Bengtsson, L., & Holme, P. (2012). Predictability of population displacement after the 2010 Haiti earthquake. *Proceedings of the National Academy of Sciences of the United States of America*, *109*(29), 11576–11581.

Maguire-Jack, K., & Font, S. A. (2017). Community and individual risk factors for physical child abuse and child neglect: variations by poverty status. *Child Maltreatment*, *22*(3), 215–

226.

Miljkovic, T., & Miljkovic, D. (2014). Modeling impact of hurricane damages on income distribution in the coastal U.S. *International Journal of Disaster Risk Science*, *5*(4), 265–273.

Morris, K. A., & Deterding, N. M. (2016). The emotional cost of distance: geographic social network dispersion and post-traumatic stress among survivors of Hurricane Katrina. *Soc Sci Med*, *165*, 56–65.

Neria, Y., Nandi, A., & Galea, S. (2008). Post-traumatic stress disorder following disasters: a systematic review. *Psychological Medicine*, *38*(4), 467–480.

Normand, S. T., Landrum, M. B., Guadagnoli, E., Ayanian, J. Z., Ryan, T. J., Cleary, P. D., & McNeil, B. J. (2001). Validating recommendations for coronary angiography following acute myocardial infarction in the elderly: a matched analysis using propensity scores. *Journal of Clinical Epidemiology*, *54*(4), 387–398.

Norris, F. H., Friedman, M. J., Watson, P. J., Byrne, C. M., Diaz, E., & Kaniasty, K. (2002). 60,000 disaster victims speak: part I. An empirical review of the empirical literature, 1981-2001. *Psychiatry*, *65*(3), 207–239.

Peduzzi, P., Dao, H., Herold, C., & Mouton, F. (2009). Assessing global exposure and vulnerability towards natural hazards: the disaster risk index. *Natural Hazards and Earth System Sciences*, *9*(4), 1149–1159.

Porter, M., & Haslam, N. (2005). Predisplacement and postdisplacement factors associated with mental health of refugees and internally displaced persons: a meta-analysis. *JAMA*, *294*(5), 602–612.

R Core Team. (2017). *R: a language and environment for statistical computing*. Vienna, Austria:

R Foundation for Statistical Computing. Retrieved from https://www.r-project.org/

Ramachandran, V., & Walz, J. (2015). Haiti: where has all the money gone? *The Journal of Haitian Studies*, *21*(1), 26–65.

Rashid, S. F., & Michaud, S. (2000). Female adolescents and their sexuality: notions of honour, shame, purity and pollution during the floods. *Disasters*, *24*(1), 54–70.

Rosenbaum, P. R. (2004). Design sensitivity in observational studies. *Biometrika*, *91*(1), 153–164.

Rosenbaum, P. R. (2010). *Design of observational studies*. New York, NY: Springer New York.

Rosenbaum, P. R., & Rubin, D. B. (1983). The central role of the propensity score in observational studies for causal effects. *Biometrika*, *70*(1), 41–55.

Rubenstein, B. L., Lu, L. Z. N., MacFarlane, M., & Stark, L. (2017). Predictors of interpersonal violence in the household in humanitarian settings: a systematic review. *Trauma, Violence, & Abuse*, 1–14.

Rubin, D. B. (2005). Causal inference using potential outcomes: design, modeling, decisions. *Journal of the American Statistical Association*, *100*(469), 322–331.

Sloand, E., Killion, C., Yarandi, H., Sharps, P., Lewis-O'Connor, A., Hassan, M., … Campbell, D. (2017). Experiences of violence and abuse among internally displaced adolescent girls following a natural disaster. *Journal of Advanced Nursing*, *73*(12), 3200–3208.

Spangaro, J., Adogu, C., Ranmuthugala, G., Powell Davies, G., Steinacker, L., & Zwi, A. (2013). What evidence exists for initiatives to reduce risk and incidence of sexual violence in armed conflict and other humanitarian crises? A systematic review. *PLoS ONE*, *8*(5), e62600.

Standing, K., Parker, S., & Bista, S. (2016). Grassroots responses to violence against women and girls in post-earthquake Nepal: lessons from the field. *Gender and Development*, *24*(2),

187–204.

Stark, L., Warner, A., Lehmann, H., Boothby, N., & Ager, A. (2013). Measuring the incidence and reporting of violence against women and girls in liberia using the "neighborhood method." *Conflict and Health*, *7*(1), 20.

StataCorp. (2017). Stata statistical software. College Station, TX: StataCorp LLC.

Stoltenborgh, M., van IJzendoorn, M. H., Euser, E. M., & Bakermans-Kranenburg, M. J. (2011). A global perspective on child sexual abuse: meta-analysis of prevalence around the world. *Child Maltreatment*, *16*(2), 79–101.

Temple, J. R., van den Berg, P., Thomas, J. F., Northcutt, J., Thomas, C., & Freeman, D. H. J. (2011). Teen dating violence and substance use following a natural disaster: does evacuation status matter? *American Journal of Disaster Medicine*, *6*(4), 201–206.

Titov, V. V., Gonzalez, F. I., Bernard, E. N., Eble, M. C., Mofjeld, H. O., Newman, J. C., & Venturato, A. J. (2005). Real-time tsunami forecasting: challenges and solutions. *Natural Hazards*, *35*(1), 35–41.

Traskin, M., & Small, D. S. (2011). Defining the study population for an observational study to ensure sufficient overlap: a tree approach. *Statistics in Biosciences*, *3*(1), 94–118.

Tsuchiya, N., Nakaya, N., Nakamura, T., Narita, A., Kogure, M., Aida, J., … Tomita, H. (2017). Impact of social capital on psychological distress and interaction with house destruction and displacement after the Great East Japan Earthquake of 2011. *Psychiatry and Clinical Neurosciences*, *71*, 52–60.

United Nations Children's Fund. (2018). *UNICEF humanitarian action for children 2018*. New York, NY. Retrieved from www.unicef.org/appeals

United Nations, & European Union. (2018). *Technical report on statistics of internally displaced*

persons: current practice and recommendations for improvement. Luxembourg. Retrieved from https://doi.org/10.2785/414331

United Nations, General Assembly. (2015). *Transforming our world: the 2030 agenda for sustainable development*, A/RES/70/1. Retrieved from https://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E

United Nations Office for the Coordination of Humanitarian Affairs. (2019). *Global humanitarian overview 2019*. Retrieved from www.unocha.org/datatrends2018

United States Geological Survey. (n.d.). M 7.0 - Haiti region. Retrieved from https://earthquake.usgs.gov/earthquakes/eventpage/usp000h60h/shakemap/intensity

Weems, C. F., Watts, S. E., Marsee, M. A., Taylor, L. K., Costa, N. M., Cannon, M. F., … Pina, A. A. (2007). The psychosocial impact of Hurricane Katrina: contextual differences in psychological symptoms, social support, and discrimination. *Behaviour Research and Therapy*, *45*(10), 2295–2306.

Weitzman, A., & Behrman, J. A. (2016). Disaster, disruption to family life, and intimate partner violence: the case of the 2010 earthquake in Haiti. *Sociological Science*, *3*, 167–189.

Willman, A., & Marcelin, L. H. (2010). “If they could make us disappear, they would!” Youth and violence in Cité Soleil, Haiti. *Journal of Community Phychology*, *38*(4), 515–531.

World Health Assembly. (1996). *Prevention of violence: a public health priority*, No. WHA 49.25. Retrieved from https://apps.who.int/iris/handle/10665/179463

Zubizarreta, J. R., Cerdá, M., & Rosenbaum, P. R. (2013). Effect of the 2010 Chilean earthquake on posttraumatic stress: reducing sensitivity to unmeasured bias through study design. *Epidemiology*, *24*(1), 79–87.

Zubizarreta, J. R., Small, D. S., & Rosenbaum, P. R. (2014). Isolation in the construction of

natural experiments. *The Annals of Applied Statistics*, *8*(4), 2096–2121.

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Declaration of interest

None.