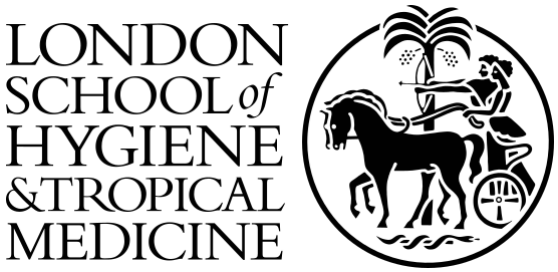

Understanding and measuring the complex relationship between natural disasters and violence against children

Ilan Salvador Cerna-Turoff

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DECLARATION BY CANDIDATE

I, Ilan Salvador Cerna-Turoff, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Ilan Salvador Cerna-Turoff **20 August 2020**

ABSTRACT

Background:

Violence against children is thought to increase after natural disasters, but evidence is limited. Methodological questions of how to measure possible associations are similarly unanswered. This thesis addresses these gaps by analyzing the relationship between natural disasters and violence against children, with emphasis on the 2010 Haitian earthquake, and by advancing design-based approaches for inference.

Methods:

The thesis is comprised of four related studies: (i) a systematic review and meta-analysis of the association between natural disasters and violence against children; (ii) a systematic review of pathways to violence; (iii) a matched-pairs analysis of violence against girls and boys after internal displacement from the 2010 Haitian earthquake; and (iv) a simulation comparing bias reduction properties and accuracy of matching designs, with sexual violence against girls displaced to a camp as the motivating example. The first two components synthesize background literature, the third component is empirical, and the fourth is methodological.

Results:

The meta-analysis found no clear association or directional effect, albeit with a limited number of studies that exhibited methodological weaknesses. Further systematic review identified five pathways to violence. In delving into one aspect of exposure, internal displacement from the 2010 Haitian earthquake was not associated with long-term violence. Sensitivity analysis, however, indicated that sexual violence against girls and physical violence perpetrated by authority figures against boys were sensitive to

unobserved covariates. Full matching incorporating an instrumental variable can mitigate measured and unmeasured biases to increase the accuracy of inference.

Conclusion:

This thesis begins to elucidate and quantify the relationship between natural disasters and violence against children. The findings identify gaps in knowledge and pathways to violence for future study. Additional high-quality research is needed to unpack the complex relationship. The methods piloted in this thesis present promising tools, particularly after rapid-onset natural disasters and in resource scarce settings.

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LIST OF ABBREVIATIONS

ATE	Average Treatment Effect
ATT	Average Treatment Effect on the Treated
aOR	Adjusted Odds Ratio
CACE	Complier Average Causal Effect
CDC	Centers for Disease Control and Prevention
CI	Confidence Interval
CP AoR	Child Protection Area of Responsibility
CRC	Convention on the Rights of the Child
CRED	Centre for Research on the Epidemiology of Disasters
DAG	Directed Acyclic Graph
DHS	Demographic Health Survey
DV	Domestic Violence
EPBR	Equal Percent Bias Reducing
FGD	Focus Group Discussion
FGM	Female Genital Mutilation
GDP	Gross Domestic Product
GIS	Geographic Information System
GLMM	Generalized Linear Mixed Models
ICT	Information and Communication Technologies
IDMC	International Displacement Monitoring Centre
IDP	Internally Displaced Person
IFRC	International Federation of Red Cross and Red Crescent Societies
IOM	International Organization for Migration
IMO	Information Management Officer
IRB	Institutional Review Board

IV	Instrumental Variable
MANCOVA	Multivariate Analysis of Covariance
MINUSTAH	United Nations Stabilization Mission in Haiti
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
OR	Odds Ratio
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PTSD	Post-Traumatic Stress Disorder
RCT	Randomized Controlled Trial
SD	Standard Deviation
SDG	Sustainable Development Goal
SITA	Strongly Ignorable Treatment Assignment
SMD	Standardized Mean Difference
STROBE	Strengthening the Reporting of Observational Studies in Epidemiology
SUTVA	Stable Unit Treatment Value Assumption
UN	United Nations
UNFPA	United Nations Population Fund
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations Children's Fund
UNISDR	United Nations International Strategy for Disaster Reduction
US	United States
VACS	Violence Against Children Survey
WASH	Water, Sanitation, and Hygiene
WHO	World Health Organization

GLOSSARY OF KEY TERMS

Child	Individual below the age of 18
Childhood	Early developmental stages of life that entail rapid physiological, cognitive, and socioemotional growth
Coping	Individual, group, or community approaches to respond to and deal with stressful situations
Disaster	A disruption that adversely affects human populations to such an extent as to overwhelm coping capacities and necessitate external aid
Emotional violence	Psychological or verbal forms of abuse and harm
Humanitarian emergency	Equivalent to *disaster*
Internal displacement	Forced movement within national borders that is spurred by natural or man-made disasters
Man-made disaster	Armed conflict, political violence, terrorism, or failure of a man-made system that adversely affect human populations
Natural disaster	Geophysical, meteorological, hydrological, and climatological disruptions that adversely affect human populations
Physical violence	Cruel or degrading treatment that involves corporal harm, punishment, torture, or physical forms of bullying or hazing
Rapid-onset natural disaster	A disaster event that usually has a clear start point and occurs over a relatively short timeframe
Sexual violence	Coerced or forced sexual acts and harassment

Slow-onset natural disaster	A disaster event that often does not have a clear start point and occurs over a long timeframe
Violence	Abuse, maltreatment, or intentional use of force or power meant to cause harm

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CHAPTER 1. BACKGROUND

1.1 Introduction

In 1976, Michel Lechat [1] made an impassioned plea at the Proceedings of the Royal Society of Medicine for the increased usage of epidemiology to understand how natural disasters affected population health:

> Disaster epidemiology is born from the increasing realization that the effects of natural disasters on the health of populations are amenable to the study of epidemiological methods…The effectiveness of various types of assistance and the long-term effect of aid on the restoration of predisaster conditions could be evaluated. To say that natural disasters are so diverse that nothing can be systematized is basically an excuse for inaction. If epidemiology is the study of health and disease in populations then there is absolutely no reason why disaster-struck populations cannot be studied by epidemiological methods. Drought in Somalia, an avalanche in Peru or floods in Florence may not have much in common, but they are surely no dissimilar than cholera in mid-nineteenth century London, amyotrophic lateral sclerosis in Guam or lung cancer… (Lechat [1], p. 422).

Since then, epidemiologists and public health researchers increasingly have documented the social and health impacts of natural disasters. The field of mental health has been particularly prolific [2–5], with other fields in nascent stages of development [6–9]. Despite the growth of knowledge, little is understood on the relationship between natural disasters and violence against children. Basic information documenting the strength of the association and description of the pathways that lead to violence is all but missing. Methodological questions about how to best measure possible associations in the post-disaster environment similarly remain unanswered.

This thesis attempts to fill a gap in the academic literature on the relationship between natural disasters and violence against children. The bounds of current understanding are first determined in a systematic review and meta-analysis identifying the magnitude and strength of the association between natural disasters and physical, emotional, and sexual violence and the quality of the evidence in Chapter 5. The subsequent analysis in Chapter 6 explores how natural disasters may lead to violence by mapping pathways identified in

a systematic review of peer-reviewed and grey literature. In Chapter 7, I present an original empirical analysis of violence against children after internal displacement from the 2010 Haitian earthquake which applies a methodological framework that avoids many of the current pitfalls in the evidence base. The original research in this thesis culminates in Chapter 8 by introducing a blended design approach which has the potential to reduce biases and strengthen the accuracy of inference within this nascent subject area. In exploring the underlying mechanisms, pinpointing effects, and proposing methodologies, this thesis seeks to inform future research on violence against children in natural disaster contexts.

1.2 Defining terms

The following sections define three core concepts central to this thesis: natural disasters, childhood, and violence against children.

1.2.1 Natural disasters

The boundaries of what constitutes a natural disaster[1] can be best understood by interrogating each part of the term individually. The first element is how one defines *natural*. Traditional natural disaster taxonomy distinguishes between events that have weather, climate, or geophysical causes and technological or man-made disasters [10]. In some cases, the divide is artificial. Human consumption and deforestation are key drivers of climatic change that exacerbate the frequency and intensity of natural disasters [11–14]. Certain environments are naturally prone to have seasonal wildfires, for instance, but changes in forest growth patterns from human activities and increasing temperatures

[1] The literature synonymously applies the terms *natural catastrophes* or *natural hazard-induced disasters* [24, 623, 624].

worsen underlying vulnerabilities [15]. Fracking has been linked to earthquakes [16–18] and flooding to overdevelopment and rising sea levels [19, 20]. In creating a separate category for man-made disasters, the disaster terminology avoids directly confronting this paradox of the human causation of some natural events. This thesis acknowledges that natural disasters often have an anthropogenic component but restricts its operational definition to traditional ecological hazards of geophysical, meteorological, hydrological, and climatological disasters (refer to Table 1 for an in-depth description). Ecological hazards are alternatively categorized by the speed of their onset—rapid- and slow-onset natural disasters [10, 21]. These terms are used sparingly and solely referred to when pertinent to the topic of discussion. Natural disaster classification can further include biological drivers of disasters, such as epidemics, and interactions between the earth and celestial bodies and forces [22]. While broadly adhering to the definition of natural disasters, these phenomena likely have different exposure characteristics and effects on populations in terms of health and violence that are outside of the purview of this thesis.

Table 1. Schema for natural disaster classification

Disaster subgroup	Definition	Disaster main type	Disaster subtype	Disaster sub-subtype
Geophysical	A hazard originating from solid earth	Earthquake	Ground movement	
			Tsunami	
		Mass movement (dry)	Rockfall	
			Landslide	
			Ash fall	

		Volcanic activity	Lahar	
			Pyroclastic flow	
			Lava flow	
Meteorological	A hazard caused by short-lived, micro- or meso-scale extreme weather and atmosphere conditions that last from minutes to days	Extreme temperature	Heat wave	
			Cold wave	
			Severe winter conditions	Snow/ice
				Frost/freeze
		Fog		
		Storm	Extra-tropical storm	
			Tropical storm	
			Convective storm	Derecho
				Hail
				Lightning/thunder
				Rain
				Tornado
				Sand/dust storm
				Winter storm/blizzard
				Storm/surge
				Wind

				Severe storm
Hydrological	A hazard caused by occurrence, movement, and distribution of surface and subsurface freshwater and saltwater	Flood	Coastal flood	
			Riverine flood	
			Flash flood	
			Ice jam flood	
		Landslide	Avalanche (snow, debris, mudflow, rockfall)	
		Wave action	Rogue wave	
			Seiche	
Climatological	A hazard caused by long-lived, meso- or macro-scale atmospheric processes ranging from intra-seasonal to multi-decadal	Drought		
		Glacial lake outburst		
		Wildfire	Forest fire	
			Land fire (brush, bush, pasture)	

	climate variability			

The Emergency Events Database [22] general classification categories which build upon earlier guidance for natural disaster measurement [23, 24].

The second concept is what makes something a *disaster*? The United Nations International Strategy for Disaster Reduction (UNISDR) [21] defines a disaster as: "A serious disruption of the functioning of a community or society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources" (p. 9). Inherent in this definition is the idea that disasters must strike in an area that is inhabited and adversely affect human populations to such an extent that they need outside help. This conceptual underpinning is central to why natural disasters are considered a humanitarian emergency equivalent to armed conflict or mass population displacement and how natural disasters came to be included in guidelines for humanitarian service provision [25, 26].

1.2.2 Childhood

Childhood encompasses early developmental stages of life that involve rapid physiological, cognitive, and socioemotional growth [27–30]. Childhood is near universally understood as a period of development and change. In contrast, the social dimensions of childhood are highly contested, hinging upon time period, legal precedent, and sociocultural tradition. This thesis adopts a broad definition of children as people under the age of 18. This age limit reflects standardized global norms established by the United Nations General Assembly's passing of the Convention on the Rights of the Child

(CRC) in 1989 [31].[2] The CRC today is the most widely ratified human rights convention in history, with every member state signing, except for the United States of America[3] [32].

Despite the legal obligations for signatory States that have ratified the CRC, the age of childhood is still contested. Some countries occasionally create their own domestic legal age limits for childhood that conflict with the CRC. As recently as 2016, India passed an amendment to its child labor law which defined people below the age of 14 as children and entitled them to special protections [33]. A universal age limit of 18 does not always map exactly onto other aspects of international operations and societal definitions. The primary multilateral agency tasked with defending child rights, United Nations Children's Fund (UNICEF), employs the CRC definition of childhood [34], while the World Health Organization (WHO) uses three other age categories for health purposes—it defines *adolescents* as a group between 10 and 19 years of age, *youth* as individuals between the ages of 15 and 24, and *young people* as a combination thereof [35, 36]. In the field of violence against women, adolescent girls from the age of 15 are classified as *women of reproductive age*, especially if married and with children [37, 38]. To further complicate matters, many non-Western cultures define childhood as the completion of specific ceremonies and types of work which may reduce the age of childhood to below 18 years or extend childhood into middle age or later life with no pre-defined age cut-off [39].

1.2.3 Violence against children

Article 19 of the CRC [31] defines violence against children as "…all forms of physical or mental violence, injury and abuse, neglect or negligent treatment, maltreatment or

[2] The CRC was reinforced in the 1990 African Charter on the Rights and Welfare of the Child [625].
[3] From here forward, shortened to "United States".

exploitation, including sexual abuse". This definition has been echoed in subsequent global policy documents, notably the 2002 World Report on Violence and Health [36] and the 2006 United Nations Study on Violence against Children [40]. The World Report on Violence and Health [36] defines violence against children as: "The intentional use of physical force or power, threatened or actual, against a child, by an individual or group, that either results in or has a high likelihood of resulting in actual or potential harm to the child's health, survival, development or dignity" (p. 5). A common measurement strategy is to divide violence into four main categories—(i) physical violence; (ii) emotional violence; (iii) sexual violence; and (iv) neglect—with the fourth category of neglect occasionally excluded or subsumed under the other categories of violence [36, 41, 42]. The narrowing of violence categories builds coherence, but it is often still too broad to understand the nuances of each form of violence. For example, is one incident of physical violence sufficient to be deemed a *case*, or does a repeat pattern need to exist? Should sexual harassment be considered equal to perpetration of rape in severity? Violence researchers have addressed this problem by further dividing each category of violence into a series of questions on specific behavioral acts.[4] This thesis explores physical, emotional, and sexual violence and within each category, uses definitions from UNICEF's [41] *Hidden in Plain Sight* report to operationalize violence.

Table 2. The Hidden in Plain Sight report's operational definition of physical, emotional, and sexual violence

Violence type	Behavioral acts
Physical violence	- Inhume, cruel, and degrading treatment or corporal punishment by any person,

[4] The use of behavioral acts for measurement can be traced to an instrument, known as the *Conflict Tactics Scale*, which measures a range of strategies that families use to resolve conflict [90]. It is one of the world's most commonly used tools for measuring violence [626].

	including: hitting (‘smacking’, ‘slapping’, ‘spanking’) children with the hand or with an implement; kicking; shaking or throwing children; scratching; pinching; biting; pulling hair or boxing ears; caning; forcing children to stay in uncomfortable positions; burning; scalding; or forced ingestion - Physical bullying and hazing by adults or by other children - Torture
Emotional violence	- Psychological maltreatment and mental abuse, such as: scaring; terrorizing and threatening; exploiting and corrupting; spurning and rejecting; isolating; ignoring; and favoritism - Denying emotional responsiveness - Insulting; name-calling; humiliating; belittling; ridiculing; hurting a child’s feelings; or another form of verbal abuse - Placement in solitary confinement or isolation, or the humiliating or degrading conditions of detention - Psychological bullying and hazing by adults or other children which includes by way of information and communication

	technologies (ICTs), such as mobile phones and the Internet (also, known as "cyber-bullying")
Sexual violence	- Inducement or coercion of a child by an adult, significantly older child, or child to engage in any unlawful or psychologically harmful sexual activity of any sort - The use of power, threat, or other means of pressure for sexual coercion, exploitation, or forced sexual acts

United Nations Children's Fund [41].

Similar to the concept of childhood, people interpreted violence against children differently in historic time periods, and variance exists in child-rearing practices and beliefs. A commonly cited example is the ancient Greek condoning of pedophilia which is understood as a form of sexual violence in the modern day [43, 44]. The historical age of sexual consent often corresponded with puberty but was as early as seven in some cultures [45]. Girls, in particular, were married at a young age, and marital rape was not considered a crime [46–50]. Norms related to corporal punishment likewise have shifted in recent times. Physical discipline of children in their homes and schools was common throughout most of history and often exalted within Judeo-Christian traditions [51–53]. Recent legislation indicates that public views are shifting, however. One such example is the Scottish Parliament's decision in 2018 to support a bill to ban physical chastisement of children [54]. Whereas parents' right to punish their children was seen as justifiable in previous eras, public support for even slight forms of physical punishment is waning in many Western settings today [55, 56]. A certain amount of variability continues to exist

in how cultures perceive violence, although research suggests that sexual violence and very harsh physical disciplinary practices are unanimously seen as violence across different cultures [57].

1.2.4 Summary of operational definitions

I have summarized the operational definition of each key concept in this thesis in the following table for the ease of the reader.

Table 3. Summary chart of operational definitions

Concept	Operational definition
Natural disaster	Geophysical, meteorological, hydrological, and climatological disruptions that adversely affect human populations [10, 21].
Child	Individual below the age of 18 [31].
Childhood	Early developmental stages of life that entail rapid physiological, cognitive, and socioemotional growth [27–30].
Violence	Physical, emotional, and sexual forms of abuse, maltreatment, and intentional use of physical force or power to cause harm [36, 41].

1.3 Natural disaster exposure

We now turn to the question of what constitutes exposure. Exposures are comprised of a constellation of contextual, spatial, and temporal factors. One could observe that a neighbor's house is destroyed by hurricane winds, flee to higher ground before an impending flooding, or live in a region where water supplies have dwindled due to an ongoing drought. All of these scenarios represent exposure to different aspects and types of natural disasters. Exposure, moreover, can consist of a series of interrelated natural disasters in succession. As an example, the 2004 Indian Ocean Tsunami began with an earthquake off the coast of Sumatra [58]. Several aftershocks followed, and the earthquake triggered volcanic eruptions in nearby and distant regions [59–61]. Should exposure be measured as the sum of all events, or relegated solely to the ultimate tsunami since it had the most intense effect on human populations? Exposure can be much less pronounced in other instances. Slow onset-disasters like drought usually do not have one clear start point. Exposure is cumulative over time but also variable with the ebbs and flows of precipitation, heat intensity, and water usage [62–65].

Health researchers tend to use either geographic location by region at the time of the disaster or self-reported scales of stressful experiences to denote natural disaster exposure [66–69]. Both are imperfect measurements. Close proximity to a natural disaster does not always guarantee that all people will have the same level of exposure or that the exposure will be more severe [70–72]. Likewise, no consensus exists on which aspects of exposure are most important to measure [67, 68, 73]. Scales commonly divide items into life threatening experiences that are observable, including injury, death of loved ones, and household damage, and perceived threats (e.g. fear that one may die) [67, 73]. The measurement of objective and subjective experiences aids in identifying multiple domains of exposure. The use of self-report, however, introduces the possibility of recall

bias and memory impairment from dissociative reactions to trauma [74–76]. In one of the few comparative analyses of both measurement methods, mapping of flood districts and self-report in scales exhibited good consistency ($\kappa = 0.70$) in assessing damage to property after 1992 flooding in Southern France [77]. Self-reported items within scales that are objective may be less sensitive to recall bias, but further investigation is needed to confirm if these patterns are consistent across different cultures and types of disasters.

An often-overlooked component of natural disaster exposure is displacement and movement. Individuals and families frequently are forced to relocate as part of their exposure to a natural disaster [78]. The overall effect of displacement is likely different among those who leave their countries of origin than individuals that are internally displaced within national borders. A frequently cited meta-analysis by Porter et al. [79] indicates that mental health outcomes are worse among internally displaced persons (IDPs) than refugees forced across national boundaries. Likewise, individuals that are forcefully displaced to a new a location will probably have different experiences than those who remain in affected communities (refer to Figure 1 to illustrate possible patterns of movement). Hogg et al. [80] outline the complexity in examining patterns of service usage for the treatment of mood and anxiety disorders among residents of Christchurch, New Zealand whom had different mobility patterns after the 2011 earthquake. In this longitudinal study, relocation to less affected areas of the city had adverse effects on treatment for mood and anxiety disorders one year after the earthquake (OR 1.18, 95% CI: 1.05-1.33, $p < 0.01$). In contrast, those who stayed in affected areas had lower odds of treatment for mood and anxiety symptoms than before the earthquake (OR 0.78, 95% CI: 0.66-0.92, $p = 0.01$). Interestingly, those who returned to affected communities in the first year versus those who had never left were nearly three times more likely to be treated for anxiety and mood symptomology. The dataset used in this thesis does not have

granular information on movement patterns to better characterize differences in displacement experiences. I solely attempt to disentangle the overall effect of internal displacement as one aspect of natural disaster exposure [80].

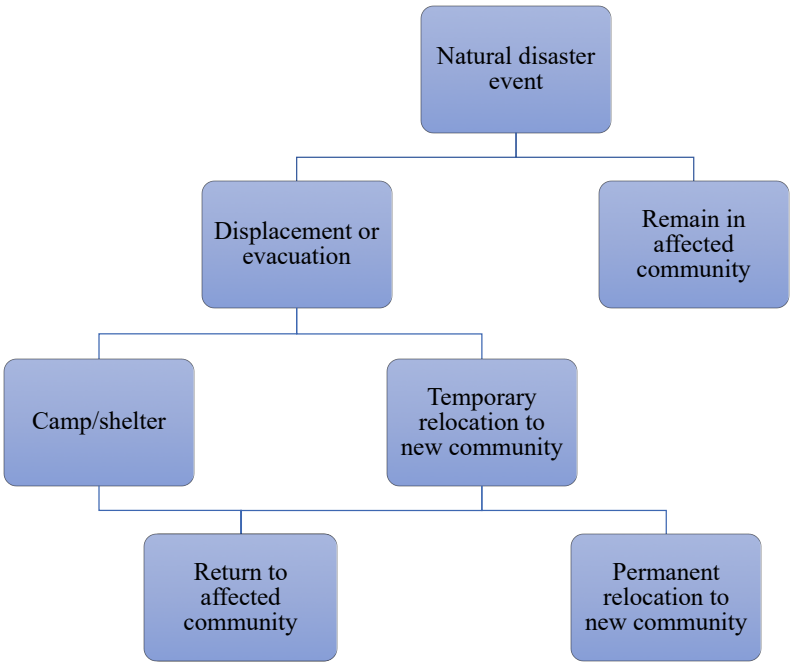

Figure 1.Possible patterns of movement during and after natural disasters

1.4 Challenges of measuring violence against children in natural disasters

Defining exposure to natural disasters is one complication in researching this subject area. Another is the challenge of measuring violence against children. Violence is difficult to measure in any setting, given that stigma and fear of reprisal leads to reporting biases [81, 82]. The developmental stage of the child (e.g. infants cannot speak or may not be aware that an action constitutes abuse), a lack of information on how to report violence, and the dependency of many children on their abusers additionally complicate the measurement of violence when perpetrated against children [83, 84]. In all instances, violence would

be underreported and often with just cause; a study examining sexual violence in childhood found that women who disclosed under the age of 18 received a higher percentage of negative first reactions than women who disclosed as adults (48% versus 15%, $X^2 = 12.76$, $p < 0.001$) [82]. Children further rely upon and trust adults and therefore, may question themselves or internalize violence as "their fault". Particularly among children that experience violence from family members, a substantive proportion partially disclose abuse and later retract their statements, leading to false negatives [85]. Recall bias also may influence patterns of disclosure. Varying degrees of amnesia and delays characterize patterns of recall among adults that experienced childhood abuse [86–89]. It is probable that children would similarly cope with past or ongoing violence by inconsistently remembering events perceived as traumatic. Overall, biases are not completely predictable, but the evidence indicates that underestimation is likely.

The choice of variable structure in measuring violence is another unresolved issue. Population-based surveys in the field of public health tend to capture violence occurrence in a binary form, while psychology studies often count the number of violent acts on a continuous scale [41, 42, 90, 91]. Both binary measures and continuous scales are limited in that they do not identify the severity of violent acts, although continuous data have the advantage of indicating if violence is isolated or ongoing. The ultimate choice between data structures for measuring outcomes is largely related to the research question, rather than the utility of the measurement. Preliminary results from a simulation study examining power and biases for violence outcomes with different data structures yielded predictable results—binary measures are best at capturing new cases and have the largest variance when violence prevalence is approximately 50%, whereas continuous measures excel at detecting reduction or cessation of violence and perform best when the treatment effect is linear across violent acts [92]. Most researchers are likely interested in both if

new cases arise and if new patterns of violence evolve as a result of a natural disaster, so both binary and continuous measures have their merits.

Natural disasters create further barriers in measuring violence against children. A hypothesis exists that natural disasters cause widespread destruction and are traumatic which increases the risk of violence against children [93, 94]. However, in these contexts, physical damage and closure of social services and schools reduce the capacity of individuals to detect or report violence [66]. The locations where natural disasters occur may have insufficient data collection systems and social service provision before natural disasters which become further compromised in the wake of a disaster [95]. The difficulty in predicting the location and occurrence of a natural disaster, mass displacement, infrastructure destruction, and mortality challenge epidemiological efforts to establish a baseline from which to measure changes in violence prevalence or other related social phenomena [96–99].

Violence studies tend to rely upon cross-sectional surveys after disaster events; routine surveillance data in locations where infrastructure happens to be intact; or the chance collection of data before a disaster event [69, 100–102]. Particularly in locations that do not have robust systems for reporting, preventing, and responding to violence against children before natural disasters, cross-sectional surveys are often the sole viable option. Cross-sectional surveys have inherent vulnerabilities to biases and present additional challenges in parsing out associations from causation, because data collection occurs at a single time point [103, 104]. Cross-sectional data, moreover, is not well-suited to understanding pathways to violence. Natural disasters may influence violence by way of mediating factors or lead to shifts in the physical and social environment that exacerbate violence over time. It is difficult to capture these pathways to violence without

longitudinal data, and these dynamics are largely not understood. Researchers are faced with a conundrum—violence against children hypothetically increases after natural disasters, and methodological obstacles exist in data collection and inference which hinder the development of an empirical foundation in these settings. It is in this intersection that I seek to develop the evidence base and methodologies for measurement. Accurate information on the scale, manifestations, and repercussions of violence after natural disasters is fundamental in determining appropriate allocation of resources for service provision, in identifying groups at highest risk of violence for prevention, and in tailoring response to serve the most vulnerable children.

1.5 Global trends in natural disasters

Natural disasters have impacted humans since time immortal. Archeological remains of a 6000 year-old man in Papua New Guinea date him as the first known victim of a tsunami [105]. We are currently experiencing an intensification of the effect of natural disasters on human populations [106, 107]. The frequency and severity of disaster events are worsening, given global climatic changes, but human settlement and activities also play a part [108–110]. The impact of natural disasters is defined by the intersection of disaster intensity and location, the structure of the built environment, and disaster preparedness. Specifically, high urban growth rates, population density, shelter construction, land use and deforestation, the existence of early warning systems, and other contextual factors determine population level effects [111–113]. Countries with a low level of development represent 11% of the population exposed to natural disasters but 53% of the casualties [112]. Recent estimates from the Centre for Research on the Epidemiology of Disasters (CRED) indicate that 315 reported disasters affected 68.5 million people and led to US$ 132 billion in economic damage in 2018 [114]. Even during a year that lacked a major

disaster event like 2018, natural disasters led to displacement of 17.2 million people [115]. Although the cummulative total of people displaced by natural disasters is unknown, the International Displacement Monitoring Centre (IDMC) estimates that an average of 25.3 million new displacements from natural disasters per year occurred between 2008 to 2016 [96].

1.6 Global trends in violence against children

Violence against children is a major public health issue that is associated with short- and long-term problems throughout the life course [116–122]. Studies have found linkages between violence and delayed cognitive development, poor academic performance, mental health disorders and suicidality, and problematic substance use and sexual risk taking to name a few [123–128]. Multiple violence types often co-occur, known as *polyvictimization*, which can magnify the negative effect on health and wellbeing [129–131]. The estimates of global violence prevalence vary widely; however, we know that violence is a common occurrence in childhood. UNICEF [132] reports that three quarters, or nearly 300 million, of children aged two to four worldwide experienced regular physical, emotional, or combined physical and emotional violence in their homes, and 9 million girls aged 15 to 19 were forced into sexual intercourse in 2017. In contrast, past year violence prevalence for children between the ages of two and seventeen was reported as over 50% of all children globally, or 1 billion children, in population-based surveys [133]. A global meta-analysis estimated that 18.0% of girls and 7.6% of boys under the age of 18 reported experiences of sexual violence [134]. Further still, the global extent of physical violence has been estimated as 17.7% and emotional violence as 26.7% [135, 136].

Differences in prevalence estimates largely emerge from variability in violence types and differences in gender, age range, and approaches to measurement. Nevertheless, when dissected further, patterns begin to emerge. Girls seem to experience a higher prevalence of sexual abuse[5], and among adolescent girls, most abuse occurs within intimate partnerships [134, 137, 138]. The majority of physical and emotional violence occurs within households. Emotional violence prevalence is fairly constant among two to fourteen year olds, but physical violence frequencies appears to be higher among young children—50% of girls and 60% of boys experienced past month physical violence at the age of two [137]. Overall physical violence measures may not differ between girls and boys, however, when age is not taken into account [135]. Prevalence tends to diverge when comparing estimates by reporting method. In two of the abovementioned meta-analyses, the prevalence of sexual violence was over 30 times higher in self-report than informant reporting [134], and physical violence was more than 75 times higher [135]. This pattern complements findings from prior research which found that disclosure of abuse was higher in self-report than in an interview format [139, 140].[6] Regional variation similarly exists across violence types. Past year physical, emotional, and sexual violence exceeded or approached 50% in Africa, Asia, and North America and exceeded 30% in Latin America among two to fourteen and fifteen to seventeen year olds. Europe had lower percentages of violence and less cases of the most severe forms of violence [133]. When considering sexual violence singularly, the highest prevalence is found in Australia for girls (21.5%) and Africa for boys (19.3%) and the lowest percentages in Asia (girls: 11.3% and boys: 4.1%) [135].

[5] Gender patterns for sexual violence are particularly difficult to disentangle. Boys may report sexual violence less often than girls because of social stigma and societal norms of masculinity, and boys may be less likely to seek or receive services after experiencing violence [627–629].

[6] A degree of measurement error is inherent in the study of violence across all reporting methods [630–632]. For instance, a study of sexual abuse child survivors found that the extent and timing of disclosure differed depending on age, fear of negative consequences, and a biological relationship with the perpetrator [83].

Policymakers increasingly have recognized that violence in childhood poses a threat to global development. The 2030 Agenda for Sustainable Development expressly commits to ending "…abuse, exploitation, trafficking and all forms of violence against and torture of children" in Sustainable Development Goal (SDG) 16.2 (United Nations General Assembly [141], p. 25). The economic costs of violence against children in the East Asia and Pacific Region alone totalled US$ 194 billion in 2012, or between 1.36% and 2.52% of the aggregate gross domestic product (GDP) using sensitivity analysis [142]. In the United States, the cost to health and social services, special education, criminal justice and productivity losses was estimated in 2015 as greater than US$ 830,000 for each case of child abuse over his or her lifetime [143].

1.7 Thesis aims and objectives

The overall aim of this thesis is to explore the relationship between natural disasters and violence against children and advance design-based approaches to inform future research in humanitarian settings.

The specific objectives were:

Objective 1: To quantify the magnitude and direction of the association between natural disasters and violence against children.

Objective 2: To identify the pathways between natural disasters and violence against children.

Objective 3: To investigate how internal displacement from the 2010 earthquake in Haiti was associated with long-term violence against children and propose a methodological framework for measuring violence after rapid-onset natural disasters in low-resource settings.

Objective 4: To introduce a design that can mitigate biases from observed and unobserved covariates and increase the accuracy of estimates in measuring the effect of internal displacement from natural disasters on violence against children within population-based surveys.

1.8 Structure of the thesis

This thesis consists of nine chapters—five background chapters and four research paper style chapters. Chapters 1 through 3 outline the thesis and present relevant background literature for framing and theory. Chapter 4 provides an overview of the thesis methodologies. Chapters 5 through 7 are original analyses on the relationship between natural disasters and violence, and Chapter 8 is a methodological paper that introduces a blended design approach that has the potential to mitigate measured and unmeasured biases and increase the accuracy of estimates in measuring the effect of internal displacement from natural disasters on violence against children within population-based surveys. Chapter 9 synthesizes the findings of the thesis and makes recommendations for future research. A summary table is provided for the reader following this section which identifies how each objective is linked to successive chapters.

Specifically:

- **Chapter 1** provides an overview of the topic, definitions, and aims and objectives of this thesis.
- **Chapter 2** outlines the literature on factors that have been identified as shifting in the post-disaster environment and bridges this evidence with the literature on associations with violence against children.
- **Chapter 3** describes theories for how natural disasters may influence violence risk for children, presents my conceptual framework, and maps the interrelationship among factors on the pathways between natural disasters and violence against children.
- **Chapter 4** describes the data used for analysis in this thesis and methodologies applied for each research paper style chapter.
- **Chapter 5** identifies the magnitude and direction of the association between natural disasters and violence against children in a systematic review and meta-analysis.
- **Chapter 6** presents a systematic review of the existing literature on how natural disasters may lead to violence and synthesizes the evidence into emergent pathways.
- **Chapter 7** functions as an empirical analysis of the effect of internal displacement from the 2010 earthquake in Haiti on long-term violence against children. It uses matching methods to quantify the odds of physical, emotional, and sexual violence and secondarily provides a framework for studying violence after rapid-onset natural disasters in low-resource settings.
- **Chapter 8** introduces a blended design approach that has the potential to reduce measured and unmeasured biases and increase the accuracy of estimates when estimating how internal displacement from natural disasters affects violence

against children within population-based surveys. It contrasts full matching, which is in the same vein as the matching method used in Chapter 7, with a novel design—known as *full matching incorporating an instrumental variable (IV)* or *Full-IV Matching*—within a synthetic dataset. The synthetic dataset was generated to be similar in structure to the data analyzed in Chapter 7. Sexual violence against girls after earthquake-caused displacement serves as the motivating example.

- **Chapter 9** synthesizes the main findings of the thesis and implications for future research.

Appendix A presents ethical approval letters from London School of Hygiene and Tropical Medicine for this analysis. Appendices B to E are supplemental files that correspond to the respective research paper style chapter.

Table 4. Overview of linkages between thesis objectives and chapters

Chapter	Related objective
Chapter 1: Background	Framing of overall thesis aims and objectives
Chapter 2: Background literature	Connected to Objectives 1 through 4
Chapter 3: Theory and conceptual framing	Connected to Objectives 1 through 4
Chapter 4: Methods	Connected to Objectives 1 through 4
Chapter 5: Systematic review and meta-analysis of quantitative literature **Research paper 1 – "Violence against children and natural disasters: A systematic review and meta-analysis of quantitative evidence"**	**Objective 1:** To quantify the magnitude and direction of the association between natural disasters and violence against children.
Chapter 6: Systematic review of literature **Research paper 2 – "The pathways between natural disasters and violence against children: A systematic review of humanitarian literature"**	**Objective 2:** To identify the pathways between natural disasters and violence against children.
Chapter 7: Statistical analysis	**Objective 1:** To quantify the magnitude and direction of the association between

Research paper 3 – "Did internal displacement from the 2010 earthquake in Haiti lead to long-term violence against children? A matched pairs study design"	natural disasters and violence against children. **Objective 3:** To investigate how internal displacement from the 2010 earthquake in Haiti was associated with long-term violence against children and propose a methodological framework for measuring violence after rapid-onset natural disasters in low-resource settings.
Chapter 8: Simulation and methodological comparison **Research paper 4 – "Pre-processing data to reduce biases: full matching incorporating an instrumental variable in population-based surveys"**	**Objective 4:** To introduce a design that can mitigate biases from observed and unobserved covariates and increase the accuracy of estimates in measuring the effect of internal displacement from natural disasters on violence against children within population-based surveys.
Chapter 9: Conclusion	Synthesis of overall thesis aims and objectives

CHAPTER 2. BACKGROUND LITERATURE

In this chapter, I trace the evidence on changes in the post-disaster environment that can lead to violence against children. The presented literature is purposefully expansive to identify a wide breadth of potential pathways between natural disasters and violence against children and to ascertain theoretical relationships with violence that are not well-documented. The overall combination of pathways to violence against children after natural disasters is unique, however specific pathways may overlap with other phenomena. Violence perpetration often relates to exploitation of vulnerabilities. As such, not all pathways are age specific or mutually exclusive from violence committed against other groups (e.g. adult migrants) [144, 145]. Violence can also reflect unequal power dynamics and an assertion of control over another. In particular, gendered pathways to violence often overlap between adult women and children, particularly among adolescent girls, although prevalence estimates likely differ [146–148]. In the following sections, I highlight evidence that explicitly mentions children. I sort the evidence in the subsequent chapter by individual, relational and household, and community levels for my conceptual framework.

2.1 Individual risk factors

2.1.1 Child behavioral problems, mental health disorders, and psychological distress

A sizable minority of children exhibit temporary or long-lasting behavioral problems following natural disasters [149]. As a selected example, a prospective study of floods in Bangladesh found that five months after the disaster, 10% of a representative sample of children between the ages of two and nine developed aggressive behavior, and 34%

developed enuresis [150]. Severe behavioral disorders can also ensue, ranging from oppositional defiant disorder and emotional dysregulation to depressive states [151–154]. An overall variability exists, but commonly, girls, younger children, and those with pre-existing mental health conditions are the worst affected demographic groups [4, 149, 155–157].

Children can develop behavioral problems or disorders directly as a result of traumatic exposure to natural disasters, but additionally, the indirect effect of maternal depression on children may affect children which similarly increases after a natural disaster [158, 159]. Evidence specific to disaster settings is limited, but a wealth of studies from stable settings have linked maternal depression to childhood behavioral problems. Maternal depression hinders cognitive and behavioral development among infants, in particular, producing an array of later behavioral problems [160–162]. A longitudinal study identified maternal depression in infancy as a risk factor for aggressive behavior towards children and for internalizing behaviors among children during middle childhood. Mothers' aggressive behaviors, in turn, led to further externalizing behaviors of children [163]. Additional cross-sectional and case-control studies have found direct associations between child behavior problems and poor mental health, physical violence, and injury of children [164, 165].

2.1.2 Loss of a parent or caregiver

Natural disasters result in high levels of mortality, particularly among women and children [166–168]. The loss of a parent or caregiver presents a profound change in a child's life [169]. Children typically experience acute grief, and some children develop psychopathology [170]. Numerous studies have documented an association between the death of a loved one and an increase in post-traumatic stress symptoms after various

natural disasters, such as Hurricane Katrina [171], a tornado exposure in the United States [172], an earthquake in China [173], and the 2004 Indian Ocean Tsunami [174, 175]. Depression may also increase. A psychological screening study after an earthquake in Turkey indicated that the loss of a parent yielded the highest odds of depression in the sample (OR = 10.96) [176]. Traumatic grief overall has been linked to behavior problems which, as described previously, increases the likelihood of physical abuse [164, 165, 169, 177–180].

Economic changes at the household level after parental death may drive child labor and marriage, which will be discussed in greater depth in subsequent sections, and are associated with experiences of violence [181–183]. As illustrated in longitudinal and representative panel data from Aceh, Indonesia five years after the 2004 Indian Ocean Tsunami, adolescent boys were more likely to take over as the head of household when their fathers or both parents died. They were 34% more likely to be working compared to boys whose parents had survived and 7% more likely to be married. Girls of a similar age experienced a 34% and 53% respective increase in housework when either their mother or both parents had died, and double orphans were 62% more likely to be married five years after the tsunami [184].

The impact of parental loss manifests in shifts in familial relationships. The surviving parent is tasked with a series of new stressors that likely affect the parent-child relationship, including coping with grief; caring for the child as a single parent; financial hardship; and additional housework and work responsibilities [185–187]. A negative coping style in managing grief and an inability to respond to children's emotional needs have been shown to affect the parent-child relationship detrimentally [169, 188]. In addition, changes in family structure due to remarriage or moving to a new household

may lead to violence. Nationally representative survey data from the United States indicates that children experience increased victimization when they live with non-biological parents [189]. Oleke et al. [190] hypothesized in a case study of orphans in Uganda that children living with extended families are at increased risk of violence, because sociocultural norms discriminate against orphans in the broader society.

Loss of parents lastly can shift the location where a child lives. Children may be sent to institutional care which is associated with high levels of child abuse [191–193]. Parental death finally may lead to the loss of one's home. Berman et al. [194] identified parental death as the catalyst for intermittent homelessness and persistent mobility between households of extended family and friends among residentially insecure young women in urban Detroit in semi-structured interviews. Unstable housing exposed girls to sexual exploitation, acute stress, and strained social support networks in the study; the death of a parent or caregiver resulted in the loss of an additional layer of protection [194].

2.1.3 Child trafficking

Vulnerabilities precipitate exploitation. Financial loss or the sudden death of a parent or caregiver causes increased poverty within households, pushing families to send children into the labor market [184, 195, 196]. Weakened social protections and policing mechanisms that follow natural disasters act as pull factors for individuals seeking to exploit vulnerabilities for profit [197]. The confluence of vulnerability and lack of social control in natural disaster settings is thought to lead to an increase in trafficking. An empirical study of 158 countries between 2001 and 2011 found that natural disasters have a strong association with domestic sexual trafficking of children, amounting to an estimated 20% increase, and a weaker association with labor trafficking, approximately a 10% increase [198].

The United Nations (UN) defines *trafficking* as the use of force, fraud, coercion, abduction, or another abuse of power to control another person with the express purpose of exploitation [199]. By definition, the combination of a lack of rights and exploitative environment lead to extreme forms of violence [200, 201]. Children, in particular, may be at heightened risk, although the evidence is severely limited. Respondent-driven sampling among female sex workers in Southern India found that those trafficked before the age of 18 had a higher percentage of any form of violence in the past six months (61.5%), as compared to women who voluntarily entered or were trafficked into sex work as adults [202]. In the Mekong Delta region, Kiss et al. [203] found that nearly half of adolescent boys experienced physical violence, and 23% of adolescent girls experienced sexual violence during trafficking within a convenience sample of children seeking services.

2.1.4 Child labor

Poverty—whether spurred by the loss of a parent or caregiver as previously described or by the loss of household livelihood which will be described in the next section—is a source of vulnerability that can drive children to work outside of the home [184, 204–206]. Representative population-based studies of the 2004 Indian Ocean Tsunami and from natural disasters in Guatemala show a significant relationship between natural disasters and child labor, and economic shocks from crop losses have been found to increase the reliance of households on child labor in longitudinal household data from Tanzania [184, 204, 207]. Work is often gendered. In examining nationally representative samples from 16 countries in Asia and Africa, girls were more involved in "invisiblized" labor in households, while boys were more often employed in family businesses [208].

Working children are likely vulnerable to violence. Prevalence estimates of physical, sexual, or emotional violence range from 25% among street-based children in four Latin American countries to 62.5% among child apprentices in Turkey [181, 209]. Accurate statistics on violence among child laborers are lacking, however, because numeration of the overall population of employed children is difficult to ascertain. Children that contribute to family business or domestic labor often are missed in counts of workers, and the illegality of child labor in many contexts incentivizes employers and children to misreport true numbers. Children also choose to support their families financially which can lead to hesitancy in reporting violence for fear of losing employment [210]. The type of labor likewise may yield variable violence rates. Children that permanently or temporarily work outside of the home are isolated from familial protection and have greater risk of violence from employers and strangers than those whom work within a family business. Although nuanced information largely does not exist, a longitudinal study identified living with non-biological families and being separated from parents or caregivers as risk factors associated with experiences of violence among children [211].

2.1.5 Child marriage

A growing body of evidence suggests that child marriage increases after natural disasters. Nationally representative studies from Indonesia and 31 sub-Saharan African countries, respectively, found increases in child marriage after environmental shocks [212, 213]. Quantitative and qualitative studies from Nepal, India, and sub-Saharan Africa cite a combination of economic insecurity and poverty, pre-existing gendered norms, and parental concerns about protecting girls from sexual harassment and violence as the underlying drivers of child marriage after natural disasters [214–217]. The highest percentages of child marriage consistently tend to be among girls from rural areas with impoverished backgrounds [214, 218, 219]. Given that poorer families face the greatest

economic insecurity, this practice is likely to become further entrenched in post disaster contexts [220]. Interviews with villages affected by flooding in Bangladesh illustrate how child marriage is a coping mechanism for acute and recurring disaster-related economic threats. Caregivers and parents mentioned that the impending loss of their houses from river erosion was the major reason for marrying their daughters in the short-term to bolster economic stability within their families. In contrast, frequent flooding reduced the amount of food available for the family, so child marriage was a strategy of decreasing the number of people to feed [221]. Nevertheless, economic reasons for increased child marriage after natural disasters cannot be isolated from gender norms that dictate that a woman's value is less than that of a man. Societies that have a stronger son preference have higher incidence of child marriage of girls overall, and the strongest positive association is among those living in extreme poverty [222].

A less obvious influence of natural disasters on child marriage relates to mortality trends. An analysis of 141 countries from the period of 1981 to 2002 found that the average mortality among women is greater than men during natural disasters and particularly among lower socio-economic groups [166]. In societies with strict gender roles and an emphasis on marriage for livelihood activities, the prompt re-marriage of men is encouraged [223]. Surviving men tend to highly outnumber women, leading to a deficit of eligible female partners [166]. Evidence from Indonesia, for instance, indicates that men tend to choose relatively younger women for remarriage which increased the average age gap from eight to thirteen years before and after the 2004 Indian Ocean Tsunami [224]. This dynamic likely is a product of existent gender norms that condone a younger age of marriage for women than men but furthermore, reflect changes in the underlying population demographic.

Child marriage may be perceived as a form of protection against violence in times of environmental vulnerability. A 2005 Oxfam International survey of selected villages after the 2004 Indian Ocean Tsunami in Indonesia, India, and Sri Lanka highlighted that a fear of sexual violence was a driving factor for the early marriage of girls among respondents [225]. Qualitative evidence elucidates this seeming contradiction. Alston et al. [226] describe how Bangladeshi families felt pressure to marry daughters after flooding to maintain the family's reputation in the community. Girls who faced sexual harassment were seen as being at higher risk of sexual violence, and sexual violence carried a stigma for both the girls and their families. Although some families may have acted out of genuine concern for their daughters' welfare, many were concerned with how the community's perception would negatively reflect on their reputation [226].

Nationally representative and population-based studies have found that child marriage increases the vulnerability of girls to violence from their spouse [183, 227–229]. Evidence from Ethiopia indicates that girls married before the age of 15 were 3.8 times more likely to have experienced forced first marital sex than young women married between the ages of 18 and 19 [228]. Similar patterns exist for emotional and physical violence. Nationally representative cross-sectional survey data from Pakistan estimates that child marriage significantly increased the odds of emotional violence (aOR 1.86, 95% CI: 1.39-2.97) and physical violence (aOR 2.44, 95% CI: 1.58-3.76) [229].

2.1.6 Child separation, accompaniment, and supervision

Natural disasters often produce mass movement of populations and lapses in familial supervision for a variety of reasons [230, 231]. First, children can become separated from their families during the course of a natural disaster or in transit to shelters or IDP camps. Other caregivers or parents may purposefully separate from their children as a pragmatic

choice in hopes of protecting them from violence and economic insecurity and allowing them to access services [230, 232, 233]. For a minority of cases, caregivers or parents are killed during the natural disaster, or the extended family does not have the capacity to foster the child, and child headed households emerge [234]. Second, parents and caregivers may migrate for working, leaving their children for periods of time, or children may travel unaccompanied by an adult to obtain shelter, food, or work [235–237]. Third, natural disasters may change work dynamics for the non-migrating adult and result in children being left unattended [238]. Nationally representative studies from Africa and Asia have indicated that women tend to spend more time and travel greater distances fetching water as a result of natural disasters [239, 240]. In an assessment of the effect of the 2015 and 2016 drought in India, for example, women spent a greater amount of time (two to six hours) and covered greater distances to fetch water each day, leaving their children unaccompanied in the process [231].

Child separation or a lack of accompaniment and supervision likely place children at risk for violence in households, in transit, and after arriving to new locations [211, 241–244]. A large gap in the evidence, however, exists on this movement after natural disasters [232]. Although based upon research in stable settings, focus groups in Rwanda, Tanzania, Uganda, and Kenya shed light on the context of violence for when girls travel alone to collect water which also may be more common in a post disaster context. Respondents described how water collection increased the predictability of women and girls' movement patterns and presented an opportunity for men to commit acts of rape, given the isolation of the trails. Upon reaching water collection points, impoverished women were coerced into sex to access water or skip long queues before water depletion. Older women with higher standing additionally were known to commit acts of physical violence against younger women in an attempt to jump ahead in the queues [245].

Children may commit acts of violence when left for periods of time and not supervised as well. In a qualitative study after Hurricane Matthew in Haiti, older children were often placed in a role of looking after younger siblings and reported using physical punishment as a disciplinary method to mimic the treatment that they had received from their caregivers and parents [233]. Child separation lastly may cause children to develop behavioral problems which pose a threat for future violence. Separation early in a child's life is associated with long-term epigenetic and biological changes, behavioral problems, and mental health disorders in several empirical studies from high-income countries [246–248]. The developmental stage of the child at the time of separation is particularly important, indicating that a separation from as little as two weeks during a child's first two years of life is associated with higher levels of child aggression at ages three and five [249].

2.2 Relational and household risk factors

2.2.1 Mental health disorders and psychological distress of caregivers, parents, or peers

One of the most documented areas of disaster literature describes negative mental health and stress reactions. The largest segment is comprised of studies on post-traumatic stress disorder (PTSD) [250–256]. A recent meta-analysis of PTSD following earthquakes estimated that the overall pooled incidence is 23.66% (95% CI: 19.34-28.27) [2]. Chen [3] found a similar elevated PTSD prevalence in a meta-analysis of floods, with a pooled estimate of 15.74% (95% CI: 11.25-20.82). Certain groups may exhibit higher PTSD symptomology than the general population, including: women; younger children; those with low social support or prior mental health conditions; and those living within heavily impacted areas [157, 257, 258]. PTSD is a logical point of entry into studying post-

disaster trauma, however natural disasters negatively impact a spectrum of mental health conditions. Prospective studies and population-based surveys from various settings indicate that the prevalence of anxiety, depression, internalizing disorders, and other mental health disorders is raised among affected populations after natural disasters [154, 259–263]. Beyond pathological manifestations of mental health, natural disasters additionally are associated with general psychological distress [264, 265]. Mental illness and distress are established factors that increase the risk of violence against children [266–268].

2.2.2 Adult and intimate partner problematic substance use

A mediated relationship between natural disasters, problematic substance use, and violence against children likely exists. Under a self-medication hypothesis, problematic alcohol and drug use is a means to offset vulnerabilities in self-regulation of affects, self-esteem, relationships, and self-care after painful or traumatic events [269]. Bushfires in Australia had a dose-response relationship with heavy alcohol use [270]; the odds of binge drinking increased in prospective study of Hurricane Katrina [6]; and hazardous drinking was exacerbated in a representative cluster survey following the Nepal earthquakes of 2015 [271]. Problematic usage of other substances, such as cigarettes and marijuana, were similarly associated with exposure to hurricanes Rita and Katrina [272–274]. Problematic substance use often exhibits gendered patterns when disaggregated. Longitudinal study of residents of the Japanese city of Higashi-Matsushima before and after the Great East Japan Earthquake and resulting tsunami, for instance, found that adult men but not women significantly exhibited problematic alcohol use ($p < 0.001$) [275]. A large-scale study that synthesized evidence across 10 disaster events echoed these findings and further concluded that natural disasters may exacerbate underlying substance abuse disorders, rather than induce alcoholism [276]. Empirical evidence indicates that

natural disasters have a direct relationship with problematic substance use, but an indirect pathway may also exist by which substances are used to offset subsequent mental health sequelae [277–279]. Problematic substance use has been identified as a known risk factor for perpetration of acts of violence against children by adult caregivers and against adolescent girls by intimate partners in non-disaster settings [147, 280].

2.2.3 Household financial strain and economic loss

Financial strain undermines parental mental health and disrupts familial relationships. Resulting feelings of depression combined with the reality of limited financial means can produce increased parental irritability, family conflict, and violence [158, 281]. A study of low-income mothers with toddlers before and after Hurricane Katrina used structural equation modeling to map how financial strain was significantly related to mothers' depressive mood, and in turn, depressive mood was associated with decreased parental efficacy. While exposure to Hurricane Katrina did not yield significant changes, it was hypothesized that chronic stressors, such as poverty, offset the acute stress [158]. This finding does not emphasize an important dimension of financial strain—the difference between a relatively stable level of poverty before and after a natural disaster as opposed to an economic shock. Consistently across other studies of natural disasters, loss of one's home and employment are significantly associated with mental health disorders [259, 282–285]. A loss of livelihood among displaced and non-displaced people after the 2004 Indian Ocean Tsunami in Southern Thailand was independently and significantly associated with PTSD, anxiety, and depression [259], and national data from the United Kingdom similarly indicated that storm- or flood-related damage to one's home in the past six months was associated with common mental disorders ($p = 0.005$) [283]. The collective evidence seems to suggest that major financial loss, and not general financial strain, leads violence against children by way of mental health disorders. More evidence,

however, is needed to parse out the dimensions of livelihood that are most predictive of poor mental health outcomes. Regardless of the mechanism, both financial strain and loss are independently associated with harsh disciplinary styles of parenting [286–288].

2.2.4 Impairment of family functioning

A limited body of evidence supports the hypothesis that family function is impaired after natural disasters [289–291]. Longitudinal analysis following bushfires in Southern Australia found that affected families exhibited more irritability, fighting, withdrawal, and loss of pleasure from shared activities at both eight and twenty-six months after the disaster event than a comparison group [289]. Following Hurricane Katrina, prospective analysis of mother-child functioning identified that hurricane threat was associated with an corresponding increase in parent maladaptive coping and corporal punishment [290]. Family functioning studies have quantified that three or more stressors within a short period are sufficient to disrupt the family system [292]. The accumulation of stressors during and after a natural disaster likely exceeds this tipping point and overwhelms functioning when not counterbalanced with positive family interactions.

Several possible mechanisms exist by which violence against children could increase. Natural disasters have been associated with unhealthy coping behaviors within families, such as disproportionate fear and poor-quality communication, which can lead to increases in family conflict [289, 293]. Different interpretations and reactions to a common event also can cause disagreement. As an example, a qualitative study of Norwegian families that survived the 2004 Indian Ocean Tsunami documented how families with common ascribed meaning of the tsunami grew stronger, whereas families with conflicting understandings of what occurred and how family members behaved during the event experienced higher familial conflict and divorce [294]. In addition,

isolated studies have found increases in intimate partner violence after natural disasters [295–298], and intimate partner violence between parents or caregivers often overlaps with violence against children within households [299, 300].

2.2.5 Shifts in masculine gender roles

Men and boys who are socialized to have a patriarchal view of gender are more likely to appraise situations that threaten their traditional gender roles as stressful. Factor analysis of psychometric scales has found that these concerns cluster in the domains of physical inadequacy; emotional inexpressiveness; subordination to women; intellectual inferiority; and performance failures in work and sex [301]. Men with high scores have greater anger and anxiety than most men, and studies have linked interactions between ideology and gender role stress with violence against intimate partners [302–304].

Natural disasters frequently produce economic loss and rapid shifts in gender roles [168, 305–307]. A seven-year quasi-ethnographic study of the 2010 earthquake in Chile, for instance, identified short-term losses of economic roles for men and a long-term upsurge in women's economic participation and activism in communities [306]. The evidence of a connection between shifts in male gender roles during natural disasters and intimate partner violence, however, is limited and unclear. One of the only studies that compared dating violence prevalence between evacuated and non-evacuated adolescents after Hurricane Ike in the United States found that non-evacuated boys were more likely to experience physical and sexual violence than girls [308]. In contrast, men's feelings of loss of power and control over women's finances, fidelity, and behavior were identified as drivers of intimate partner violence against adult women in interviews with 36 individuals after Hurricane Matthew in Haiti [233]. Similar to stable settings, it may be that the subgroup of men and boys who uphold strong patriarchal ideologies of gender

and those that have asymmetrical power and age dynamics in their relationships are more likely to perpetrate violence in natural disaster settings [183, 304].

2.3 Community risk factors for violence

2.3.1 Physical changes in the environment

Natural disasters change the structure of the physical environment in a manner that may increase violence risk. An example of a flooded district in Bangladesh illustrates this interaction. The floods inundated homes, so neighbors and extended families would combine households and live under the same roof. In interviews, girls reported that they were no longer able to maintain privacy when changing clothes or menstruating which carry strong social taboos in Bangladeshi society. The increase of people within a household meant that girls would change behind cloth partitions that did not block visibility and when menstruating, would sleep on rooftops [242]. Overcrowding may lead to sexual violence within the household, and sleeping on roofs increases the likelihood that perpetrators from outside of the home can commit acts of violence against unattended girls [309–311]. The destruction of bathing sites and latrines reportedly also drove violence against children in Bangladesh. Facilities were destroyed during the floods, and as a result, girls would open defecate and bathe in secluded areas away to gain privacy, risking sexual violence [242].

The humanitarian response likewise introduces new elements into the physical environment. Camps may be examples of “deviant places” where the ecology of the place is paramount in producing violence and not necessarily the composition of the inhabitants [312]. Camps exhibit the kinds of social disorganization that have long been associated with deviance and crime. High residential mobility exists, as large influxes of people from

different neighborhoods and social groups mix in a new space and destabilize predictability in a child's environment [244, 313–315]. Evidence from a three-wave nationally representative study of victimization in the United States corroborates that residential instability is predictive of multiple forms of child abuse inside and outside of households [314]. In addition, former systems of social protection no longer exist in camp communities to protect children from violence outside of their households [244, 316]. Neighbors, teachers, and other adults in a child's community act as a larger social safety net. Displacement disrupts these systems of protection, and fewer trusted adults may be present to watch over children in camp communities. Violence within households likewise may increase. Household overcrowding is common phenomenon in camps, as members of different households combine. Prospective data from Australia has linked household overcrowding with sexual abuse of children, and geographic patterns from the United States show a connection between overcrowding and neighborhood crime. It is hypothesized that the increased stress of living in a confined space and ease of committing exploitative acts within the home increases sexual violence [309, 317]. Furthermore, the poorest of the poor tend to be displaced to camps or shelters, as they lack options to rebuild or resources to move to new areas where they have social connections [102, 244, 318]. Poverty and unemployment have been associated with child abuse in stable settings, and an increase of both factors in camps may intensify violence [319, 320].

The construction of camp infrastructure can encourage violence. The rapid influx of people in a short timeframe often means that planning within camps is haphazard, or informal camps emerge that are not managed or policed by any organizational body [244, 321]. Even when camps are intentionally planned, policing bodies are often unable to meet the protection needs of the affected population because of limited staffing and capacity [321]. A common issue is that tents and shelters are insecure because of their

nonexistent locking mechanisms and flimsy construction material [311, 315, 322, 323]. A household survey in IDP camps after the 2010 Haitian earthquake identified that the most common location where women and girls experienced sexual violence was their tents. Similarly, the lack of street lights and absence of lighting and locking mechanisms on latrines posed problems for safety and security [322].

Schuller's [244] in-depth ethnographic study of the humanitarian aid architecture after the 2010 Haitian earthquake is one of the best indictments of how aid operations can foster the risk of violence against children. Haitians traditionally live in *lakou*—intergenerational households with a shared yard that developed after plantation slavery. Camp management distributed identical tents to each family based on principles of equity, and food distribution allocated food rations to women household heads as a gender-sensitive policy. While well-meaning policies, the structure of humanitarian aid rewarded large families to split into subunits, and adolescent girls with young children commonly formed their own households to maximize food distribution. The ingenuity of the IDP population inadvertently also increased the risk of sexual violence against isolated girls who slept in separated tents [244].

2.3.2 Influx of new actors

Natural disasters activate a complex humanitarian architecture in which national or international aid workers and other associated industries are deployed [324]. Businesses emerge that supply goods and services and seek to profit from the opening of a new market by investing in infrastructure and resource extraction [325, 326]. Actors may exploit the lack of oversight and social disorganization to commit violence against children [310]. Extreme power asymmetries also exist in terms of position, citizenship, and economic status. In the specific case of international actors, they largely can act with

impunity because of the weakened local judicial system and the difficulty of prosecuting cases that require extradition [327, 328]. Humanitarian aid workers have been implicated in numerous cases of sexual violence against children over the past decades. In a 2002 watershed study by the United Nations High Commissioner for Refugees (UNHCR) and Save the Children-United Kingdom, focus groups and interviews with 1500 refugees and stakeholders in Liberia, Sierra Leone, and Guinea discovered that aid workers from various agencies, including the UN, were demanding sex from girls under 18 for food, medication, skills training, and other commodities and services. In total, 42 agencies and 67 individuals were implicated in this behavior [329]. A 2008 Save the Children report on sexual violence committed by aid workers and UN peacekeepers in Cote d'Ivoire, South Sudan, and Haiti implicated 23 separate humanitarian agencies and reported sexual abuse, harassment, and trading sex for food and non-monetary services [327]. In a long string of scandals, Oxfam's recent failure to investigate staff members' alleged sexual misconduct with children during the 2010 Haitian earthquake response led to a major inquiry from the United Kingdom House of Commons [330, 331]. A blatant sense of invincibility was apparent in each of these cases. Humanitarian aid workers approached children while on missions and active duty and in some cases, committed sexual acts in aid distribution centers or on agency property [327, 332].

Military and security forces often form a large portion of the actors on the ground during a humanitarian response. After the 2010 earthquake in Haiti, the UN immediately pledged up to 8940 peacekeeping troops and a police component of up to 3711 police [333], and the United States military response and relief efforts constituted more than 22,200 personnel, 33 naval and coast guard vessels, and more than 300 aircraft at its peak [334]. In total, 34 national militaries deployed troops and assets to Haiti [335]. Militarism and human rights violations, particularly sexual violence against women and girls, have a

strong connection that has been documented across contexts and history [336–339]. Deployment of UN peacekeeping troops in Kosovo, Haiti, and Sierra Leone coincided with massive upswings in prostitution and trafficking of women and girls, and several missions were expelled for substantiated sexual misconduct [329, 340]. A wide swath of the military industrial complex is implicated in this behavior, including international, regional, and national military and security forces, police units, and contractors [329, 339].

Military sexual violence and exploitation of girls and boys after natural disasters follows a similar pattern. Transactional sex[7] with children is the most documented phenomenon. A qualitative study of 231 Haitians who had engaged in transactional sex with United Nations Stabilization Mission in Haiti (MINUSTAH) peacekeepers described patterns of exchanging sex for the provision of humanitarian aid and material needs, such as school fees and uniforms. UN peacekeepers additionally committed acts of physical, emotional, and sexual violence within intimate partnerships [341]. Globally, UN peacekeeping forces commit the highest documented proportion of sexual violence against minors of all UN agencies [342].

2.3.3 Changes in balances of power

Natural disasters lead to a redistribution of existing goods and the introduction of new commodities into affected communities, shifting the balance of power. Power imbalances and gender asymmetries that existed prior to the disaster event become more entrenched

[7] Transactional sex is, at times, defined as a form of violence against children and at other times, excluded from the definition [36, 41]. When transactional sex is included, it can be thought of as "structural" violence in that choice to participate is not equal across all children. A gradient exists in that older adolescents may choose to participate of their own volition, whereas younger children and vulnerable subgroups are less likely to have the developmental capacity or power to exercise free will when engaging in transactional sex. In this thesis, a narrow definition of violence is used to increase the specificity of the analyses. Transactional sex is conceptualized as a separate form of exploitation that can be correlated with or mediate future risk of violence. Natural disasters, nevertheless, would likely shift imbalances of power in favor of perpetrators and allow for more acts of violence during transactional sex [586].

and vulnerabilities more extreme [315, 343, 344]. In a similar vein to labor exploitation, unequal control of resources and power differentials may increase violence against children and particularly, girls [345]. Although commonly cited as an issue, much of the evidence is anecdotal. One of the better documented exceptions is the 2010 Haitian earthquake. The dynamics of food aid distribution after the 2010 Haitian earthquake exemplify the intersection between power and vulnerability, resource control, and sexual exploitation. International coordination bodies specified that women household heads would be the primary recipients of humanitarian aid within IDP camps in an effort to improve fair distribution within families [346]. Camp committees, typically composed of appointed community members that aid in governance within camps, were tasked with distributing food and other commodities. The camp committee members exploited their newfound position of power to demand sex from women and girls for food distribution cards and other supplies [344, 346, 347]. As a proxy indicator of the scale of the issue, a survey of women beneficiaries in Haitian IDP camps indicated that 21% were unaware that humanitarian aid was free and never to be exchanged for sex, money, or other goods [346]. Women and girls risked sexual violence from camp committee members if they refuse sexual advances or exchanges as part of aid distribution but additionally, faced further physical violence from male family members and community members when receiving money or food, because it conflicted with Haitian gender norms that centered men as primary economic providers [233, 346].

2.3.4 Breakdown of social control

An inherently Hobbesian notion is that humans need a strong state in order to maintain prosocial behavior [348]. By this logic, natural disasters breakdown systems of policing and community control which increases deviance [349]. Crime in communities is highly sensationalized after natural disasters [350, 351]. Opportunistic sexual violence, or so-

called “disaster rape”, is widely thought to increase [352]. In a pre-post population-based study six weeks after the 2010 earthquake in Haiti, 69.6% (95% CI: 49.7-89.2) of women and girls identified their attackers as “criminals” [102]. Empirical studies of physical and sexual violent crime from the United States show varying associations, however. National longitudinal data indicates that violent crime rates on the county level are associated with a larger natural disaster magnitude [353]. In contrast, localized spatial analysis from Miami following Hurricane Wilma found that hurricane exposure decreased the amount of crime on the community level, but the frequency of experiencing a hurricane positively predicted domestic violence [354]. Other studies show that rates of physical and sexual assault and rape before and after the Northridge Earthquake in California stayed stable [355], while rape and aggregated assault decreased in cities that received a large number of people displaced from New Orleans because of Hurricane Katrina [356]. Ultimately, this evidence is limited to adult samples, so it is unclear if differences exist in patterns of community violence against children. The data, furthermore, was generated in a high-income country. The patterns may differ from places where infrastructure and policing are weak prior to a natural disaster and further compromised during its occurrence [357, 358]. The 2010 earthquake in Haiti is a clear illustration of crime differences from a low-income setting. Before the earthquake, the small national police force was barely existent. Major police facilities were destroyed during the earthquake, and a large number of police officers as well as UN peacekeepers were killed [95]. In addition, 5100 prisoners escaped the main prison in Port-au-Prince and regrouped into gangs that operated in the poor neighborhoods to perpetrate violent crime women household heads [359]. MINUSTAH stepped in to support policing efforts but even these troops refused to enter IDP camps and poor neighborhoods after dark or to intervene in cases of rape and violence, citing their own security concerns [359, 360]. Reports of rampant opportunistic sexual violence were documented in communities and IDP camps [102, 321, 322].

2.3.5 Perceived breakdown of social norms

Affected individuals and communities apply their own sociocultural lens to interpret behavior and circumstances after natural disasters. Dissonance in meaning may occur when individuals perceive an action or situation in the post-disaster environment via the social norms of stable times. An example is illustrated in a qualitative study after flooding in Bangladesh. Girls were forced to wade through high waters on their way to work. Their wet clothing would cling to their bodies in a social unacceptable manner, and men would sexually harass and assault them [242]. The narrative should not be interpreted as a blaming of the victim but rather, that the floods forced girls to break with social conventions, and this misreading of women's sexually suggestive clothing as a "choice" was a driver of violence in the community. During rapid shifts that accompany natural disasters, policing of gendered behaviors can be seen as an attempt to control change in an unstable social environment and assert normative group values, often at the expense of women and girls [361–363]. Violence is an external sanction that enforces compliance with social norms [364, 365]. Similar ruptures of meaning occur in some societies after natural disasters when girls are unaccompanied in their homes or travel alone because of migration and shifting labor patterns; when girls have mixed gender interactions with men; or when children choose or are not able to abide by customary behaviors that show respect for adults. Mainly qualitative studies have documented sexual and physical violence against children after natural disasters in each of these situations [231, 233, 242, 244, 311].

2.4 Summary

This chapter presents an overview of the relevant literature for subsequent utilization in my conceptual model. The evidence describes a wide range of factors, from individual to structural, that increase the potential risk of violence against children and are useful in assembling a cohesive picture of how and why violence may occur after natural disasters. Across the studies, information is limited on the direct relationship and intermediary factors between natural disasters and violence against children, with a notable exception of studies on mental health [255, 256, 366]. The quality of the literature is likewise mixed. Qualitative case studies provide a patchwork of possible pathways to violence against children after isolated natural disasters [233, 242, 244]. The final linkage between intermediary effects and violence against children, however, is often lacking, and descriptions of possible pathways are rudimentary at best. A sizable number of longitudinal and representative cross-sectional studies have been conducted, but this information may not be generalizable, because it is not equally researched across pathways, contexts, and natural disaster types [173, 252, 306]. Certain natural disasters, particularly Hurricane Katrina in the United States and the 2010 earthquake in Haiti, have been highly studied [73, 102, 244]. Less evidence exists on other natural disasters, especially, those that occur outside of the United States or countries in the Global North [270, 354, 367]. Reoccurring or smaller disaster events are frequently missed altogether in academic study. Despite these limitations, the information provides a comprehensive base for beginning to trace mechanisms and hypothetical pathways to violence.

CHAPTER 3. THEORETICAL AND CONCEPTUAL FRAMING

This chapter details relevant theories and integrates evidence to build an explanatory model of how natural disasters may lead to violence against children. I present hypotheses of why natural disasters can produce violence in various human relationships and at each level of the social ecology. The socio-ecological model is utilized to organize the theories into a cohesive whole. I subsequently produce pathways diagrams to describe the interrelation among key variables described in Chapter 2, with a further description of how effect moderation may influence pathways to violence. In some instances, violence against children does not increase or possibly reduces after natural disasters, and therefore, it is important to explore the types of coping strategies and approaches in individual and group mobilization of resources that may counter risk [66, 294]. The final section of the chapter elaborates on how temporality complicates discussions of the pathways to violence after natural disasters.

3.1 Socio-ecological model

The socio-ecological model is a useful heuristic tool for framing how macro-level exposures from natural disasters influence interpersonal acts of violence. First created by Bronfenbrenner in 1977, it proposed that humans develop within nested social structures of families, communities, and society [368]. Belsky [369] shortly thereafter adapted the socio-ecological model to explain child maltreatment as a social-psychological phenomenon determined by individual development; the microsystem of the family; the exosystem of the community; and the macrosystem of society. In his model, children are embedded within various social systems that combine to produce violence [369]. The

socio-ecological model has become a dominant theoretical paradigm in studying violence since the 1980s [36, 370–373]. Recent extensions posit that humanitarian emergencies, such as natural disasters, likewise produce widespread changes in the social ecology that increase the risk of harm to children [93, 94, 374]. The current models that extend the socio-ecological model to humanitarian emergencies are not specific to natural disasters; they are based in their near entirety on evidence from armed conflicts or are tailored to health outcomes other than violence. This chapter provides a refined socio-ecological framework describing pathways through which natural disasters may influence the risk of violence against children.

3.2 Nested theories of violence against children

Scholars in the fields of psychology and sociology have created numerous theories to hypothesize why a natural disaster may lead to violence against children. These theories frequently cite stress as an important driver of violence among individuals, families, or couples, while a lack of social control and order form the theoretical pillar for why violence occurs outside of private spaces [349, 375–380]. In the following sections, I outline relevant theories to explain how changes at ascending levels of the social ecology may increase violence against children.

3.2.1 Individual level theory

Lazarus' classical stress theory asserts that psychological stress is caused by an appraisal of the environment which overwhelms available coping resources [381, 382]. Although not cited by name, this theoretical framing is often evoked in natural disaster literature as the reason why violence intervention is necessary after natural disasters [383]. Numerous scholars have advanced stress theories since Lazarus' foundational work [265, 377, 384],

of which Hobfoll [375] offers a particularly useful framing for natural disaster contexts and violence against children.

Hobfoll [375] laid the groundwork for a new theory of stress reactions that sought to be "more directly testable, comprehensive, and parsimonious that previous approaches" (p. 513). The conservation of resources theory asserts that humans strive to gain and protect resources and that loss is a threat. *Resources* is a loose term that encompasses objects of physical value but also conditions and characteristics that are valued subjectively. Status, economic stability, self-esteem, and loved ones are selected examples of resources that have monetary or symbolic value. The threat of loss produces stress when environmental circumstances change drastically [375]. In this view, stress is equally a measure of individual valuation and objective environmental processes that lead to deprivation [376]. Certain individuals embody loss of resources from a natural disaster as a stress reaction which may be common because of shared cultural scripts but is still variable across a population [377].

Individual stress is a driver of child maltreatment. Hillson and Kuiper's [380] stress and coping model asserts that a series of interdependent and self-reinforcing steps precede violence against children, whereby a caregiver cognitively appraises stress, applies his or her coping style, and employs behaviors consistent with certain ways of coping. During the initial appraisal of a situation, a caregiver assesses if the situation feels overwhelming and if personal or situational resources are available to mitigate the effect of the stressor. The caregiver responds in a manner that reflects his or her disposition and worldview. Each style of coping is accompanied by a proclivity towards certain types of child-rearing behaviors, some of which involve acting violently towards children [380]. This process-

oriented model translates how stress is internalized and acted upon among individuals affected by natural disasters.

3.2.2 Relational level theory

External stressors can erode healthy dynamics within relationships and the family unit. The potentially traumatic effect of natural disasters can negatively affect individuals which, in turn, affects family bonds [289, 385, 386]. Healthy functioning of the whole is diminished as a consequence. Natural disasters conversely can diminish family functioning, leading to changes in individuals [158, 289, 294]. Children and close family members may develop secondary trauma, whereby close contact with someone that has a mental health disorder or severe trauma induces a stress response in those around them [387]. The direct effect of natural disasters on individuals reflects mechanisms akin to those outlined above in individual theories for stress reactions. The indirect component of stress, however, reflects *secondary* or *vicarious traumatization*, first coined by Figley as part of systems theory [388]. By this definition, the family is comprised by a network of relationships that responds dynamically to the environment and produce higher level interactions. The whole, therefore, is greater than a sum of individual parts [389].

Direct and indirect ramifications of stress on the family system can lead to violence within families [378]. Children additionally form their own relationships and intimate partnerships. Intimate partnerships can exist between peers or can be comprised of individuals with disparate age and power relationships, typically older men and adolescent girls [390]. An entire tome could be devoted to intimate partner violence in itself. It bears mentioning that intimate partnerships are similarly a dynamic system in which individuals experience stress, influence their partners' stress levels, and cope

dyadically [391]. Natural disasters produce strains on interpersonal relationships which may lead to acts of violence [298, 392].

3.2.3 Community level theory

Social disorganization theory was first advanced as a means of explaining how community dynamics were more important than individual characteristics in determining delinquency and crime. Criminality is highly linked to location which elevates risk in a manner that is distinct from the simple measurement of perpetrator or victim demographics. Violent crime is thought to proliferate when social control is weak [379]. In the 1960s, Fritz [349] extended the theory to natural disasters, postulating that they prevented essential functions of society and led to social disorganization and criminality. Fritz' assertion does not completely agree with contemporary evidence that indicates that violence patterns are variable in communities after natural disasters [349, 354, 356, 367]. Recent scholars have proposed an amendment to this theoretical framing in stating that violence outside of private spaces occurs when governments and social service providers are unable to meet the basic needs of the affected community after natural disasters, opportunities exist for perpetrating crime without sanction, and prior inequity and social division exist [310, 393]. The impact of natural disasters, therefore, reflects the political economy and social organization of the communities where they occur and should not be seen as existing outside of the normal structure of human landscapes [393, 394].

3.3 Conceptual framework

I return to the socio-ecological model as a means of organizing the outlined evidence into a visual representation. Specific risk factors for violence against children after natural disasters from the previous chapter's literature review have been inputted into the framework on the individual, relational and household, and community level. The conceptual framework is illustrated in Figure 2.

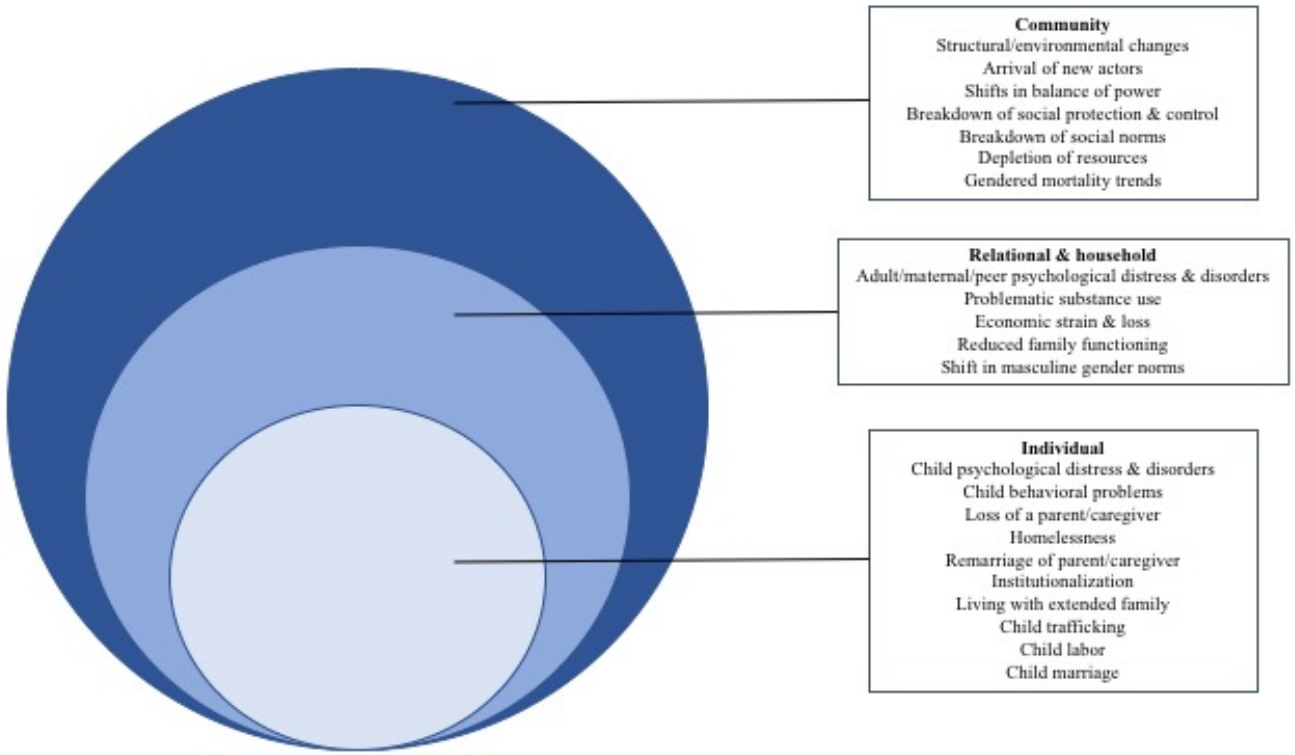

Figure 2. Socio-ecological model tailored to natural disasters and violence against children

Risk factors identified in Chapter 2 are organized in this diagram by individual, relational and household, or community levels. Following the convention of visual representations in the violence field, concentric circles are drawn to center children in the model but additionally, to recognize that children live

within “nested” organizing structures of society [36, 370–373]. Risk stems from a combination of individual characteristics and experiences as well as higher order relational, household, and community level factors. Circles are off-centered to represent this aggregation as one moves from individual to relational, household, or community risks.

3.4 Revisiting pathways to violence

The socio-ecological model is useful in conceptualizing that children are embedded within social systems. Violence, however, does not have one etiology, and singular risk factors do not encapsulate differing combinations of risk factors or interactions. Multiple risks usually co-exist and interact to increase victimization [129]. In an attempt to move beyond analyses that treat each risk factor in isolation and to better capture underlying mechanisms, I present a pathway diagram in Figure 3. Figure 3 illustrates relationships among the outlined risk factors in the previous chapter. It is further nuanced in the succeeding sections of this chapter.

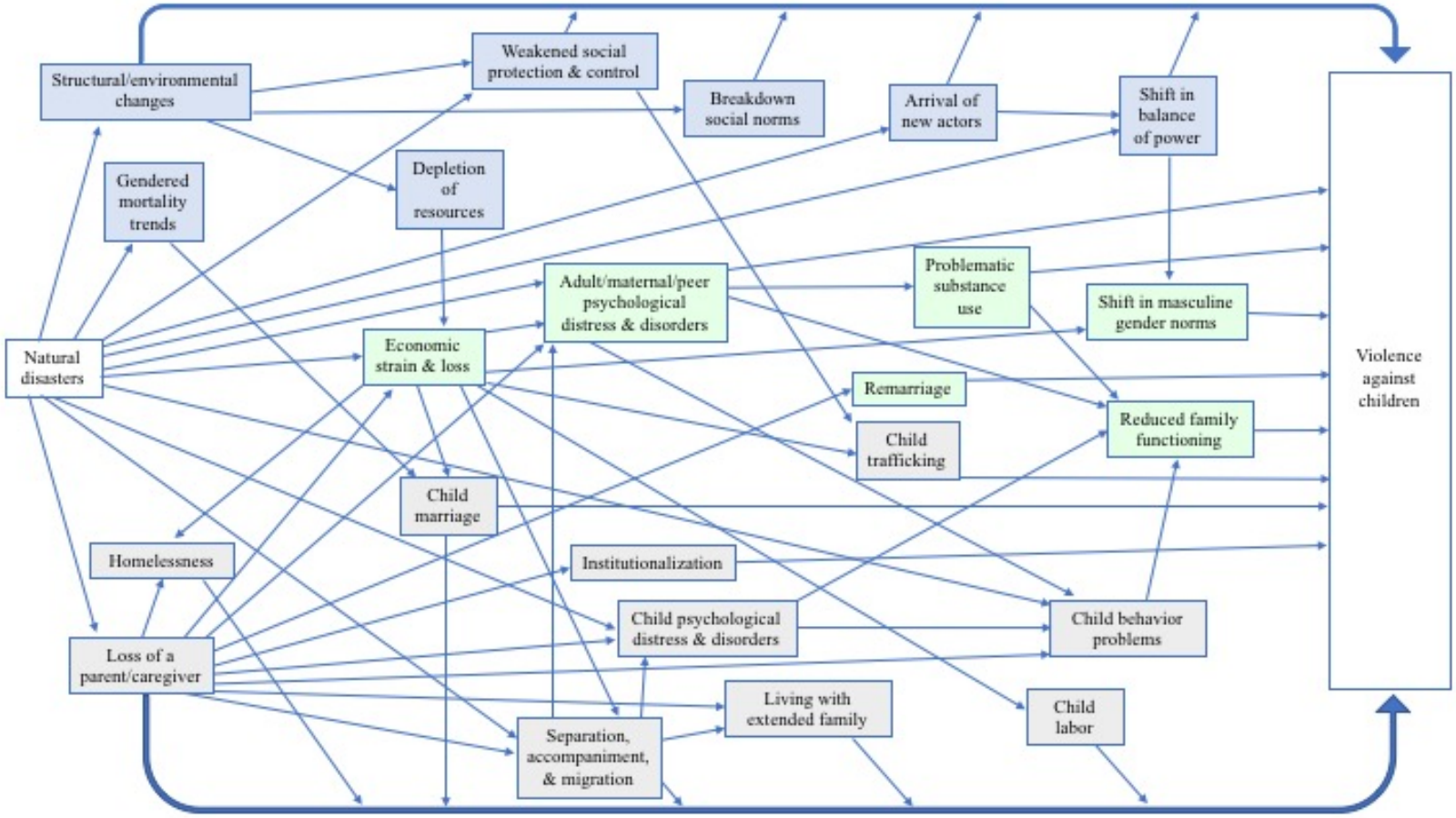

Figure 3. Preliminary diagram of pathways between natural disasters and violence against children

The evidence from Chapter 2 on risk factors is organized visually to illustrate hypothetical pathways. Factors in light grey are individual level factors; light green are relational level factors; and light blue are community level factors. Arrows indicate evidence-based linkages between factors. The diagram is unidirectional to reflect potential causal relationships, but reverse patterning could occur between several linkages at different time points. Temporal changes are not included above, given the gap in evidence from natural disaster settings and focus on cross-sectional data in this thesis.

3.5 Moderation of effect

The stress theories and risk factors presented thus far use a vulnerabilities framework for understanding the relationship between natural disasters and violence against children. Multiple contradictory examples exist of individuals, families, and communities that positively cope with the adversity and stress caused by natural disasters and in some cases, thrive [395–397]. Strengths are similar to vulnerabilities in that they are multidimensional and arise from underlying characteristics and social conditions. Higher order conditions, such as good governance and social safety nets, may promote cohesion and bolster strengths at the individual and community level. Theorists have divided individual strengths into two elements—(i) inherent qualities that operate during non-crisis periods and (ii) adaptive traits that are evoked in response to a natural disaster [398]. The latter is the focus of this section. By this definition, moderators are factors that buffer the relationship between a natural disaster and violence against children and accordingly, are mobilized in reaction to disaster exposure. Moderators can be organized into three categories of ascribed meaning, positive coping behaviors, and social support.

3.5.1 Ascribed meaning

The conceptualization of what is a disaster is fundamentally a social construct [399]. A disaster gains meaning from how people perceive the event, and wellbeing partially relates to one's outlook. In a pre-post study of Hurricane Katrina among religious and mainly low-income African American women, structural equation modeling revealed that post-disaster distress was predicted by lower levels of optimism and lacking a sense of purpose ($\mu = -0.07$, 95% CI: −0.13-−0.02, $p < 0.05$) [400]. Six months after the 2004 Indian Ocean Tsunami, a pessimistic explanatory style was most predictive of PTSD among a sample of Sri Lankans (aOR 1.30, 95% CI: 1.06-1.58, $p < 0.01$) [401]. In contrast,

respondents from qualitative studies after the 2004 Indian Ocean Tsunami in Sri Lanka, tornados and wildfires in the United States, and Hurricane Maria in Dominica identified a positive outlook as a means of buffering their stress [397, 402, 403]. Two additional studies elucidate elements of the underlying mechanisms. Interviews with 2011 Slav Lake wildfires survivors in Canada commonly described how exposure to the wildfires changed their perception of what was most important in life. Parents and children mentioned a greater appreciation of their families, less value placed on material possessions, and more focus on the current moment [404]. Among Norwegian families impacted by the 2004 Indian Ocean Tsunami, the majority similarly reported greater cohesion when they shared a common interpretation of what had occurred during the natural disaster [294].

Faith is an important lens for how many people interpret the world and is relied upon for comfort, acceptance, and attribution of greater meaning, especially when faced with existential threats [405]. Judeo-Christian beliefs hold a specific interpretation of natural disasters as trials of faith or moments of judgement [406], but natural disasters have meaning across cultural traditions. Buddhists in Sri Lanka reflected that the 2004 Indian Ocean Tsunami was representative of the "temporary nature of life" in Buddha's teachings and interpreted the tsunami as a "lesson" in relying less on material possessions [402]. Syncretic Afro-Caribbean traditions in Dominica conceptualized Hurricane Maria as the manifestation of evil spirits that spoke directly to individuals, and survival represented a successful interaction with the supernatural [403].

Religion and spirituality function in several ways to ascribe meaning during and after natural disasters. Religious congregations can offer a source of perceived social support and provide a sense of collective identity [407, 408]. Rituals may offer solace, and religious teachings may allow individuals to construct meaning out of seemingly senseless events [397, 402, 405]. Attribution of acts to divine powers permits secondary

vicarious control over the situation, because one identifies with the greater ascribed meaning of the event [409]. Respondents in qualitative studies from countries as disparate as Pakistan, Thailand, and the United States have identified religion as an important component of their coping behaviors after natural disasters [397, 410, 411]. Quantitative evidence provides further nuance in understanding how religious coping might disrupt pathways to violence. A meta-analysis of 49 studies identified that positive religious coping (seeking support and finding meaning) was associated with positive psychological adjustment (r = 0.33, 95% CI: 0.30-0.35) and lessening of negative psychological adjustment (r = −0.12, 95% CI: −0.14-−0.10) [412]. Consistent with these findings, positive religious coping was negatively correlated with symptoms of PTSD, major depression, and alcohol use in a representative sample of adults after Hurricane Katrina, whereas negative coping was associated with major depression [413]. Those who felt that an earthquake in Northern Pakistan was punishment from *Allah* for their sins or lack of divine belief had greater PTSD symptomology and stronger negative emotions, and the loss of faith was associated with worse outcomes among tsunami survivors in Sri Lanka [402, 410]. Having a religious practice may not be important in preventing violence per se, so much as possessing the ability to find meaning in the event. It would be callous not to qualify this statement. It is easier to have a positive interpretation of a natural disaster when one has not lost loved ones or life possessions, and one has economic access to supportive services [402, 414].

3.5.2 Positive coping behaviors

In times of crisis, a segment of the population takes concrete action to reduce stress and provide support to others around them [403]. Gathering information is a way that individuals feel empowered and gain a sense of control over the situation. It similarly assures individuals that they are not alone in their experiences. Gathering information on

recent events was found to significantly reduce psychological stress in a sample of individuals displaced by Hurricane Katrina ($\tau(830) = -2.22$, $p < 0.026$) [405]. Sharing stories with others is another means of orientating oneself and reducing stress [403]. The ability to discuss one's experience significantly reduced psychological stress after Hurricane Katrina ($p < 0.007$) [405]. In Sri Lanka after the 2004 Indian Ocean Tsunami, women, in particular, emphasized the importance of speaking with others to gain advice and process experiences [402].

The reestablishment of routines is a step in the progression to normalcy. Respondents in Canada after forest fires described returning to routines as a means of moving on with their lives and coping [404]. Another study from Sri Lanka described busy involvement in activities as a stress reduction mechanism. Activities can include reestablishment of routines that existed before a natural disaster, engagement in bureaucratic processes to repair damages caused by natural disasters, or building of new structures and roles [306, 402, 404]. Communities raised monuments to remember the dead as a way of healing in the wake of the 2004 Indian Ocean Tsunami in Sri Lanka, for instance [402]. The 2010 earthquake in Chile was a case in which new roles were created within society; it opened possibilities for greater voice and equality for women as they became central social organizers within communities [306].

Humor and good communication similarly aid in coping. Heron [403] describes the importance of humor as a release from the negativity of the situation after Hurricane Maria in Dominica. As one respondent aptly states, "A lot of those days after the hurricane was either laugh or cry. Because, if you don't look at the positive it will destroy you" (Heron [403], p. 127). Open communication and flexible coping styles aided in reducing conflict among Norwegian families who experienced the 2004 Indian Ocean

Tsunami [294]. In another study from the United States, parents reduced the stress of their children after wildfires and tornados by explaining the situation and remaining calm [397].

3.5.3 Social support

Strong relationships buffer the effect of stress, and integration into a large social network is a crucial element of social support [415]. Evidence from a variety of settings indicates that social support is associated with better mental health outcomes and self-control of behaviors after natural disasters and conversely, that low social support produces significant distress and psychological disorders [258, 410, 416–419]. A mixed methods study on the mental health effect of social network dispersion after Hurricane Katrina indicated that distance positively predicted post-traumatic stress symptoms and a reduction in perceived social support. The qualitative component of the study identified possible mechanisms behind reductions in social-psychological functioning; respondents reported feeling a lack of deep belonging in their new relationships and communities and were unable to fulfill obligations to distant ties [420]. The cohesion of the community can also affect individuals apart from their embeddedness within social networks. Community cohesion has been identified as reducing psychological disorders among public health workers after hurricanes in the United States, even after adjusting for relevant individual measures of support and wellbeing [419], and collective gatherings were found to reduce post-traumatic growth in earthquake-affected communes in Chile ($r = 0.155$, $p < 0.01$) [416].

Social connections function to provide emotional and material support. The negative association between flood-related stress and postnatal maternal depression, for instance, significantly declined when intimate partners provided women with informational

support ($\tau(140) = -2.42$, $p = 0.017$) and emotional support ($\tau(140) = -2.43$, $p = 0.016$) [421]. Families likewise described increased feelings of connectedness to one another after experiencing Canadian wildfires [404], and parents reported a 12% increase in contact with social networks and their children after tornados in the United States [397]. In the material domain, survey participants reported a 24% increase in reliance on their kin for material support in the form of supplies, debris removal, and home repairs after Hurricane Andrew in the United States. African Americans were 1.5 times more likely to receive support from kinship networks, and the working poor constituted the largest percentage of affected families (37.3%) that relied on their extended networks for housing [395].

Natural disasters may aid in the forging of new relationships and in producing greater community social cohesion [397, 404, 420, 422]. Swedish adolescents described hugging and speaking with strangers in hospitals as a source of support after the 2004 Indian Ocean Tsunami [396], and communities in Canada described creating new relationships and engaging in deeper conversations with neighbors, friends, and coworkers after wildfires [404]. Hurricane Maria in Dominica created a liminal space that disrupted the social order and permitted new social bonds. Heron [403] describes a narrative of a young man that found refuge in the home of a local businessman from a higher socio-economic class. The hurricane temporarily reduced class divisions. Kinship bonds additionally were created where they had not existed before. Many people who survived the storm by sheltering in the same household continued to live together after it had passed, and neighbors borrowed from one another to create collective meals [403].

3.6 Moderated pathways to violence

The reviewed evidence and conceptual theory suggest that moderation has a role in influencing the effect of natural disasters on violence against children. Moderation, therefore, can affect accurate measurement and is important to document in research. To this end, I present a second pathway diagram in Figure 4 that includes the outlined moderators from the current evidence base.

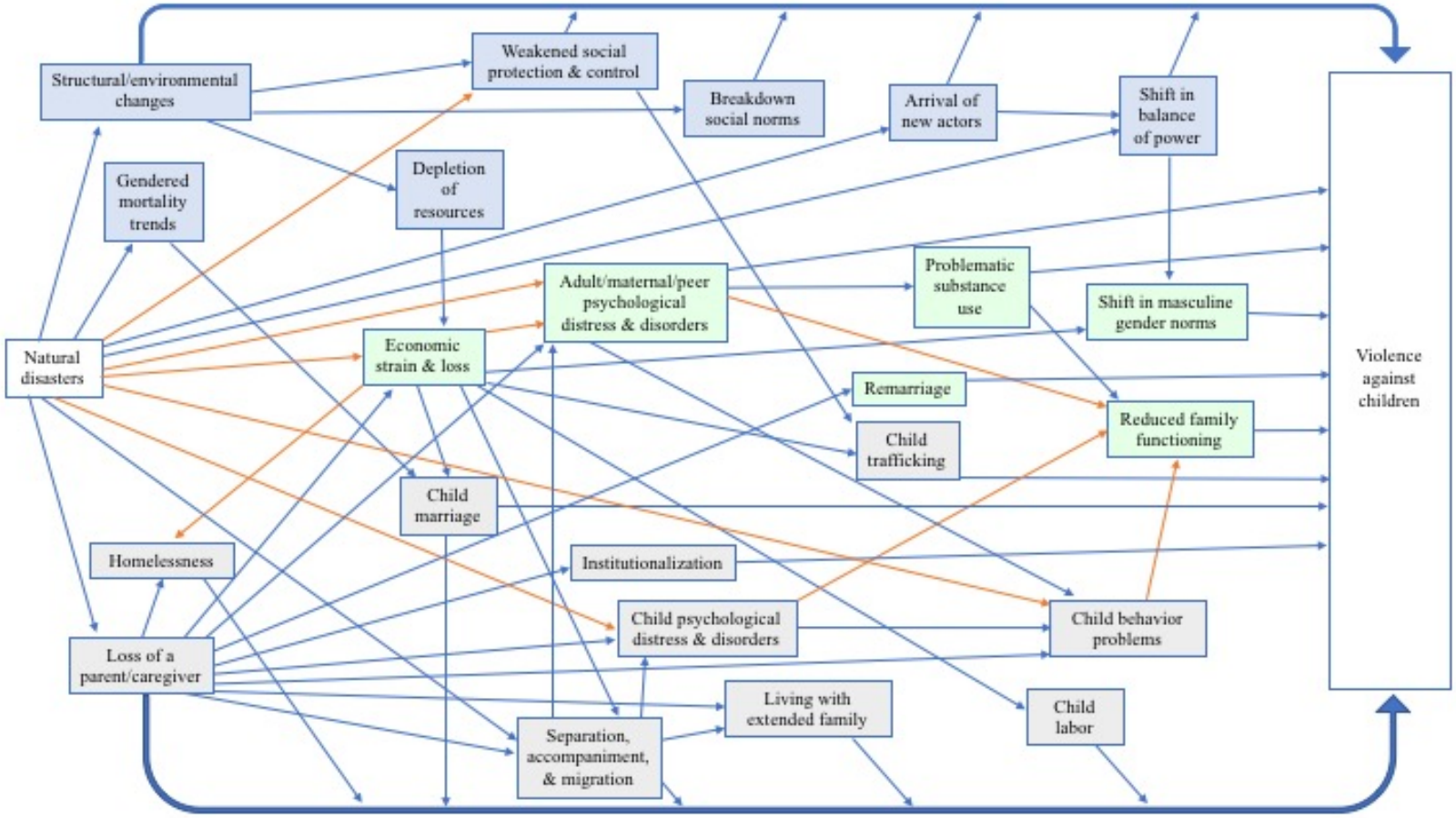

Figure 4. Moderated pathways between natural disasters and violence against children

Arrows highlighted in orange are pathways between natural disasters and violence against children that could be moderated.

3.7 Temporal change

A final point that bears mentioning is that the relationship between natural disasters and violence against children is not static. Acute stress from natural disaster exposure may exert a fleeting influence on violence against children. Limited data indicate that violence incidence peaks and rapidly declines in the first six months after some natural disasters, with differences across locations, disaster types, and forms of violence [66]. One possible explanation is that certain segments of the population experience delayed stress reactions and mental health disorders that do not immediately manifest after natural disasters, leading to longitudinal patterns of violence that are not linear [149, 423]. A second hypothesis is that natural disasters may deepen vulnerabilities and alter the risk of violence against children over time. Norris and Uhl [424] found that secondary stressors significantly mediated the relationship between various types of acute stress from exposure to Hurricane Hugo and depression, anxiety, and somatization in a sample from the United States. Economic loss may deepen as time progresses and worsen stress reactions [424], and qualitative study of family adjustment to displacement from Hurricane Katrina found that coping processes are dynamic and shift over time [425]. The literature has yet to document extensively how human reactions to transformations in the post-disaster environment relate to violence against children.

3.8 Summary

In the following chapters, I apply my conceptual framework as a guide for exploring the relationship between natural disasters and violence against children. Each chapter contributes to centralizing and furthering the evidence on this relationship. Chapter 5 measures direct quantitative associations that can be drawn between natural disasters and violence against children, and Chapter 6 maps the current evidence and describes pathways to violence. Isolation of the effect of a macro-level exposure like natural disasters on interpersonal acts of violence against children further justifies careful and rigorous designs. I implement this vision in an empirical analysis of secondary data in Chapter 7 and in introducing a blended design approach in Chapter 8 that can reduce biases and increase the accuracy of inference.

CHAPTER 4. METHODS

This thesis uses a variety of methods—systematic review of literature, meta-analysis, and data analysis of matched-pairs—to explore the relationship between natural disasters and violence against children and concludes by introducing a blended design approach that can reduce biases and strengthen the accuracy of inference in the future. The first component of the thesis in Chapter 5 is a systematic review and meta-analysis of peer-reviewed literature to evaluate the magnitude and direction of the association between natural disasters and violence against children. The counterpart is a systematic review of existing peer-reviewed and grey literature to identify pathways between natural disasters and violence against children in Chapter 6. In an applied example, I analyze nationally representative cross-sectional survey data to estimate the effect of internal displacement from the 2010 Haitian earthquake on physical, emotional, and sexual violence against children in Chapter 7. I lastly generate a synthetic dataset similar in structure to the data analyzed in Chapter 7 for a simulation study. In this final research paper style chapter (Chapter 8), I introduce a blended design approach that can mitigate biases caused by observed and unobserved covariates and increase the accuracy of estimates on the effect of internal displacement from natural disasters on violence against children in population-based surveys. Sexual violence against girls after displacement from the 2010 Haitian earthquake serves as the motivating example.

This chapter provides an overview of the research designs and data analyses contained in this thesis. Further details on the methodologies can be found within each research paper style chapter.

4.1 Data sources

Peer-reviewed quantitative literature (research paper 1)

The first systematic literature review and meta-analysis identified original quantitative studies on the association between natural disasters and violence against children. I searched 15 academic databases for publications in the English language from the earliest date of publication to May 16, 2018. The search identified 1045 unduplicated articles, and eight were eligible for inclusion.

Peer-reviewed and grey literature (research paper 2)

The systematic literature review on pathways between natural disasters and violence against children examined English language publications in 21 academic databases and grey literature repositories from the earliest date of publication to May 16, 2018. Grey literature was additionally solicited from 12 focal points within agencies that lead the global child protection response in humanitarian emergencies and all UNICEF Child Protection Coordinators and Information Monitors worldwide. 6276 unduplicated publications were identified in the search, and 26 were eligible for inclusion.

Population-based survey (research papers 3 and 4)

The Violence Against Children Survey, or VACS, is a nationally representative cross-sectional household survey that comprehensively measures violence in childhood. The VACS is led by the Centers for Disease Control and Prevention (CDC) as part of the Together for Girls Partnership and is administered in countries that do not have comprehensive surveillance systems which, in practice, constitutes low- and middle-income countries [42]. Since 2007, it has been administered in 24 countries globally [426]. It was the first nationally representative household survey on physical, emotional, and sexual violence against children in Haiti. The Haitian VACS used a stratified,

randomized three-stage cluster design to collect representative samples of girls and boys, aged 13 to 24, who resided in separate clusters, including within IDP camps. Sampling occurred on the household level and consisted of a short demographic questionnaire conducted with the head of each selected household and an in-depth survey with one girl or boy per household. Child questionnaires consisted of a series of over 900 questions on violence, contextual factors, health outcomes, and behavioral risks. The survey was administered in Haitian Kreyol in 2012 [427]. The English translation of the responses was used for this secondary data analysis.

4.2 Research designs and analyses

In this section, I summarize the research designs and analyses used in the subsequent chapters of this thesis. All studies described are presented as research papers. Two papers have been published, one paper is currently under review, and the last is being prepared for submission.

Research paper 1: "Violence against children and natural disasters: a systematic review and meta-analysis of quantitative evidence"

See Chapter 5, pages 99-119

The first research paper is a systematic review and meta-analysis of quantitative literature. I systematically searched academic databases for articles that measured quantitative associations between natural disasters and physical, emotional, and sexual violence against children. The second author and I independently double screened the returned studies, determined if they met the inclusion criteria, and assessed their risk of bias. The study applied a three-level random effects model, with 95% CI, to pool the results. This model can be expressed via the formula:

$$Y_{rsd} = \gamma_{000} + u_{00d} + r_{0sd} + e_{rsd}$$

where γ_{000} is the overall fixed effect or grand mean; u_{00d} is the random effect of each independent study sample; r_{0sd} is the random effect of multiple outcome measures within each study; and e_{rsd} accounts for random effects of individuals [428]. This form of "multi-level" meta-analysis is particularly warranted to reduce second order sampling bias and increases power when a limited number of studies exist [429]. Categorical estimates were converted to logarithmic odds and synthesized as odds ratios, given the scarcity and small sample size of studies with continuous outcomes. I subsequently conducted a subgroup analysis, using a set protocol established *a priori* and quantitative and visual heterogeneity assessments to determine reporting. Subgroups that did not exhibit heterogeneity were assessed for publication bias using contour-enhanced funnel plots.

This systematic review and meta-analysis supports Objective 1 of this thesis. The output of the research is a published paper, presented in Chapter 5.

Research paper 2: "The pathways between natural disasters and violence against children: a systematic review of humanitarian literature"

See Chapter 6, pages 120-163

The second research paper is a systematic review of pathways between natural disasters and violence against children. In research papers 1 and 2, I applied consistent operational definitions of natural disasters, violence, and children to create Boolean search terms and systematically examined academic databases and grey literature repositories. I additionally solicited recommendations from experts within key agencies that respond to

child protection issues in humanitarian emergencies in order to increase access to grey literature sources not posted publicly. The first and second author independently double screened and assessed the returned literature for inclusion and risk of bias. The first, second, and third authors applied an inductive process of thematic analysis. We identified themes using a constant comparative method, grouped the information within the included articles into emergent themes, and described pathways. Thematic analysis is an umbrella term for a wide range of different qualitative techniques for identifying patterns within a text [430]. A constant comparative method combines the rigor of set coding for themes with iterative revisiting and adjusting of constructed categories to ensure that they have meaning [431]. Based upon the finalized list of pathways, I proposed tailored interventions that could stymie specific routes to violence after natural disasters. Intervention designs differ for each pathway which underscores the importance of understanding pathways in creating humanitarian programming.

This systematic review supports Objective 2 of this thesis and complements the first research paper. My analysis resulted in a research paper that is currently under review and is presented in Chapter 6.

Research paper 3: "Did internal displacement from the 2010 earthquake in Haiti lead to long-term violence against children? A matched pairs study design"

See Chapter 7, pages 164-191

The third research paper analyzes the effect of internal displacement from the 2010 Haitian earthquake on long-term physical, emotional, and sexual violence against girls and boys. I applied a rigorous approach to target the causal effect of a decomposed element[8] of earthquake exposure—internal displacement—on violence outcomes.

[8] Decomposition is the process of separating a measurement into key elements which aids in specificity and reduction of high dimensionality [633].

I matched children within the VACS into pairs that were similar, except for their experience of displacement. The matching process involved four key steps. First, I selected theoretically relevant variables with appropriate data structures in the VACS and pre-processed the data to create matching covariates reported as occurring before displacement and therefore, less likely to be biased by experiences during or after displacement. This step importantly ensured that the exposure[9] was independent of the measured covariates. Since these covariates occurred before natural disaster exposure, they were not listed in the prior conceptual framework which described factors on the pathway to violence against children. Second, I used the propensity score to trim individuals outside of the area of common support. The *propensity score* is the probability of exposure given an individual's observed covariates, and the *area of common support* is the overlapping area in which the exposed group has candidate counterfactuals for matching [103, 432]. The propensity score collapses multiple covariates into a quantitative value which aids in identifying individuals within the comparison group that are similar to individuals in the exposed group for matching. Trimming removes units from the comparison group that are systematically different from those in the exposed group, increasing inference quality and removing outliers that would be incomparable in studying the effect of displacement [103]. Third, I specified the characteristics of my matching methods, namely sampling without replacement and optimal pair matching. Sampling without replacement, or the use of each control once in matching to treatment individuals, is analogous to the real world where individuals experienced treatment at one time point and aligns with the effect of internal displacement from the earthquake [433]. In practice, I applied a one-to-one pair match design and chose to optimally match pairs

[9] When referring to observational data, I use the term "exposure", instead of treatment assignment, and "exposed and comparison groups", instead of treatment and control groups. Otherwise, I use typical causal language to describe methods more generally.

which selects control matches in a manner that reduces overall within-pair distance in the sample [434]. Optimal matching by definition reduces bias more than nearest neighbor matching (so-called *greedy* or *step-wise* multivariate algorithms), but the extent of the bias reduction in covariate balance between treatment and control groups as a whole depends on the selected matching method [435]. The choice to use optimal matching thus was a precaution to reduce bias to the greatest extent possible; however, the bias reduction may have been minimal. In the final step, I compared various matching algorithms to identify the method that most reduced imbalance between displaced and non-displaced groups by assessing balance criteria quantitatively (via standardized mean differences) and visually (via love plots). Covariate balance was compared across six algorithms: (1) propensity scores, (2) Mahalanobis distance, (3) Mahalanobis distance with a propensity score caliper, (4) rank-based Mahalanobis distance, (5) Euclidean distance, and (6) Euclidean distance with a 0.2 caliper. I selected the algorithm that most reduced the standardized mean difference for pre-earthquake sexual violence for girls and physical violence within households for boys which are theoretically and empirically important drivers of violence identified in past studies from Haiti and other contexts [134, 436]. Euclidean distance with a 0.2 caliper[10] was utilized for design. By matching, I reduced bias across the entire covariates space, and by choosing the best matching method, I increased exchangeability between matched pairs to isolate the effect of displacement [437, 438]. I additionally assessed the quality of the trimming and matching prior to statistical analyses by calculating the sample sizes necessary to detect effects similar to those found in past surveys from Haiti and creating decision trees to explore characteristics of unmatched children. The former indicates if the sample is sufficiently

[10] Euclidean distance is the shortest, straight-line distance between two points in space [634]. A caliper determines the maximum width of difference allowable between the treatment and control groups and is calculated in standard deviations. Cochran and Rubin [635] originally suggested that this value be set at 0.2 to eliminate approximately 99% of bias from confounding for linear treatment effects. It has since been applied with categorical data [636].

powered to detect small changes in effect sizes after preprocessing the data, and the latter aids in identifying any possible excluded but important subgroups.

Once a matching method was selected, I applied McNemar's test to identify differences in violence outcomes that occurred after earthquake displacement within matched pairs. McNemar's test is a non-parametric test for paired categorical data [439]. I carefully explored possible biases as part of interrogating the strength of the results. I conducted tests of missingness to identify differences between exposed and comparison groups and tests of covariance to see if internal displacement affected multiple violence types differently than singular forms of violence. I lastly applied gamma sensitivity tests to understand how likely the results would change in the presence of unmeasured biases. Sensitivity testing identifies the threshold for *p*-values at which outcomes become significant or insignificant. Given that observational data is often highly influenced by biases from unobserved covariates, sensitivity testing is an important and useful way to determine the robustness of one's results [103, 440]. In conjunction with the main analysis of the study, I created supplemental visuals to facilitate understanding in Geographic Information System (GIS) mapping of earthquake exposure and in producing a Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) chart of overall study design.

This research paper is linked to Objectives 1 and 3 of the thesis and yielded new empirical evidence on the relationship between natural disaster exposure and violence. It further established a methodological framework for studying violence after rapid-onset natural disasters in low-resource settings. The output of the analysis resulted in a published research paper which is presented in Chapter 7.

Research paper 4: "Pre-processing data to reduce biases: full matching incorporating an instrumental variable in population-based surveys"

See Chapter 8, pages 192-220

The fourth research paper uses Monte Carlo simulation to introduce a novel design approach, known as *full matching incorporating an instrumental variable (IV)* or *Full-IV Matching*, which has the potential to reduce biases from observed and unobserved covariates and increase the accuracy of inference within population-based surveys. I compared biases and the accuracy of two matching-based designs—(i) full matching and (ii) Full-IV Matching—within a synthetic dataset. The synthetic dataset was generated to be similar in structure to the Haitian VACS analyzed in research paper 3. An epidemiological study which seeks to estimate the effect of internal displacement to a camp setting on sexual violence against girls is used as a motivating example.

Monte Carlo simulation is an empirical experimental technique of pseudo-random number generation that can assist in evaluating biases among statistical methods [441]. The strength of simulation is predicated on the fact that the researcher created and therefore, knows the underlying values in the dataset and can compare how estimates align or diverge with the true estimand [442]. My models for generating the exposure and outcome are based upon the subsequent outlined equations. All background covariates occurred before displacement from the earthquake. The covariates are self-explanatory, with the exception of *restavek* status, which is a form of indentured slavery unique to poor children in Haiti. I incorporated an additional unobserved covariate of *social capital* and suitable IV of *earthquake damage* which were not found in the original dataset used in research paper 3. The former was included to illustrate how each matching method mitigated unmeasured biases. The latter was incorporated, because the original Haiti VACS did not contain a suitable variable that could be used as an IV. I further

transformed a binary covariate into a categorical and added interaction terms to create non-additive effects and diversify data structures.

Displacement into camp (exposure):

$$Pr(Y = 1) = g(\propto_0 + \propto_2 Z + \propto_1 X_1 + \propto_2 X_2 + \propto_3 X_3 + \propto_4 X_4 + \propto_5 X_5 + \propto_6 X_1 X_2)$$

Sexual violence each girl (outcome):

$$Pr(Y = 1) = f(\beta_0 + \beta_e e + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_2 X_3)$$

Z = severity of earthquake damage

e = exposure

X_1= age

X_2= past sexual violence

X_3 = living with parents

X_4 = *restavek* status

X_5 = social capital

g, f = inverse logit functions

I first applied a traditional matching metric—Mahalanobis distance—combined with an optimal full match [443, 444]. Mahalanobis distance is a standardized measure of Euclidean distance in a multi-dimensional space [445]. This approach in matching differs from propensity scores in that it treats all covariates as equally important[11] [446, 447]. The matches, moreover, are based on the covariance matrix, so they are less sensitive to being unequally influenced by individually large or small covariates [446]. Full matching

[11] Matching that reduce bias for both individual matches and overall covariate balance falls into a general class of equal percent bias reducing (EPBR) methods [446].

optimally produces matched sets that have a variable number of individuals so as to create weighted treatment and control groups. Because information is drawn from multiple individuals to build composite profiles, a greater amount of that data can be utilized than in pair matching which reduces standard errors and increases precision [444, 448].

Full matching was subsequently compared to Full-IV Matching. Full-IV Matching is a blended design approach that I created for this analysis. In essence, the algorithm matches sets of individuals that have similar covariate distributions and matches on far values of the IV to create polar extremes of encouragement [449]. I first converted the continuous IV to high and low categories by carving out weak middle values. I set a high cut-off value for the IV for illustrative purposes which encourage girls strongly to be displaced or not to be displaced (lower 10^{th} quintile and upper 90^{th} quintile). The full matching component used Mahalanobis distance, as in the comparison matching algorithm outlined above. Since matching algorithms create pairs or sets of individuals that have similar composite scores for their background covariates, high-to-low values of the IV first must be translated before matching with the IV [432, 444]. Current statistical software packages cannot execute this approach with optimal full matching, and so, I wrote and shared useable code in R [450–452].

I assessed how each design mitigated measured and unmeasured biases by examining balance statistics for key covariates before and after full matching and Full-IV Matching. Quantitative differences between exposed and comparison groups across key covariates were described as standardized mean differences (SMD). I used generalized linear mixed models to compare how accurately each design estimated the true effect of internal displacement to a camp setting on sexual violence against girls created as part of the data

generation function of the synthetic dataset. Confidence intervals were empirically bootstrapped for the estimates.

This analysis is linked to Objective 4 of the thesis and advances a methodologically rigorous design that can improve the quality of future studies on violence against children after natural disasters. The output of the analysis resulted in a research style paper which is presented in Chapter 8.

4.3 Research ethics

London School of Hygiene and Tropical Medicine provided initial ethics approval on August 4, 2017 and approved an amendment on November 21, 2018 for the abovementioned research (reference: 14413; see Appendix A for letters of ethics approval). Research papers 1 and 2 synthesize data that are publicly available. Research papers 3 and 4 are based on secondary data analysis of the de-identified VACS which is publicly available upon request from the Together for Girls Partnership. The CDC Institutional Review Board (IRB), the Interuniversity Institute for Research and Development IRB, and the Ministry of Public Health and Population's National Ethics Committee in Haiti gave ethics approval for primary data collection. Written consent was obtained from the head of each selected household and assent from the child respondent before participation [427].

CHAPTER 5. RESEARCH PAPER 1 - MAGNITUDE AND DIRECTION OF THE ASSOCIATION

This chapter provides a systematic review and meta-analysis of the association between natural disasters and violence against children (Objective 1). Past conceptual framing posit that a direct linkage exists between natural disasters and violence against children, and current humanitarian programming operates under the assumptions that violence universally increases [93, 94, 383]. I sought to test the strength and direction of the association for physical, emotional, and sexual violence to build a greater empirical foundation on the topic and understand the scope and quality of the current literature.

 The supplementary materials referenced in the manuscript are provided at the end of the thesis as Appendix B. The numbering of the references in Appendix B match the bibliography at the end of the chapter for ease of referencing.

5.1 List of tables

5.2 List of figures

London School of Hygiene & Tropical Medicine
Keppel Street, London WC1E 7HT

T: +44 (0)20 7299 4646
F: +44 (0)20 7299 4656
www.lshtm.ac.uk

RESEARCH PAPER COVER SHEET

Please note that a cover sheet must be completed for each research paper included within a thesis.

SECTION A – Student Details

Student ID Number	1514051	**Title**	Mr
First Name(s)	Ilan Salvador		
Surname/Family Name	Cerna-Turoff		
Thesis Title	Understanding and measuring the complex relationship between natural disasters and violence against children		
Primary Supervisor	Dr Susannah Mayhew		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

SECTION B – Paper already published

Where was the work published?	PLoS ONE		
When was the work published?	30/05/2019		
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion			
Have you retained the copyright for the work?*	**Yes**	Was the work subject to academic peer review?	**Yes**

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Stage of publication	Choose an item.

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	I conceptualized and designed the review and meta-analysis; screened the articles; conducted the analyses; and wrote the manuscript.

SECTION E

Student Signature	[redacted]
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RESEARCH ARTICLE

Violence against children and natural disasters: A systematic review and meta-analysis of quantitative evidence

Ilan Cerna-Turoff[1]*, **Hanna-Tina Fischer**[2], **Susannah Mayhew**[1], **Karen Devries**[1]

1 Department of Global Health and Development, London School of Hygiene and Tropical Medicine, London, United Kingdom, **2** Department of Population and Family Health, Mailman School of Public Health, Columbia University, New York City, New York, United States of America

* it2208@caa.columbia.edu

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Abstract

Objectives

Reviews of violence against children in disaster settings focus on armed conflict. Little is understood about natural disasters which has implications in planning humanitarian response. We examined the magnitude and direction of the association between exposure to natural disasters and physical, emotional, and sexual violence against children, and assessed the quality of the evidence.

Methods

We searched 15 health and social science databases from first record until May 16, 2018. Publications describing all types of quantitative study design were eligible for inclusion. We presented study characteristics and quality in a narrative form and generated pooled estimates using a three-level random effects model. We evaluated Cochrane's *Q* with *p*-values below 0.10 and radial plots to assess heterogeneity. Planned subgroup analyses explored differential results by violence form, study design, and analysis method.

Results

11 publications met inclusion criteria. The majority were cross-sectional studies examining physical or sexual violence in the United States. We found no evidence of a consistent association or directional influence between natural disasters and violence against children. Combined categorical violence outcomes had substantial heterogeneity [Q (df = 66) = 252.83, $p < 0.001$]. Subgroups without evidence of heterogeneity had confidence intervals that included a possible null effect. Our findings were mainly limited by inconsistencies in operational definitions of violence, a lack of representative sampling, and unclear establishment of temporal order between natural disaster exposure and violence outcomes.

Conclusions

Based on the available evidence, we cannot confidently conclude that natural disasters increase the level or severity of violence against children above non-disaster settings, however heterogeneity and study quality hamper our ability to draw firm conclusions. More nuanced and rigorous research is needed to inform practice and policy as natural disasters increasingly affect human populations.

Introduction

Natural disasters are increasing in severity and frequency due to climatic changes [1–3] and adversely affecting a greater number of people worldwide [4,5]. In 2016, forced displacement from natural disasters accounted for 24.2 million new displacements across 118 countries and territories; three times the number of people displaced from conflict-related events in the same period [6]. The United Nations International Children Fund (UNICEF) estimates that approximately 535 million children were affected by natural disasters and other forms of disasters in the same year [7].

A widely assumed negative health outcome of natural disasters is violence against children. Natural disasters elevate known risk factors for violence in non-disaster settings; such as, caregiver stress, food insecurity and poverty, community substance abuse, and mental health disorders in both caregivers and children [8–10]. These risk factors do not occur in isolation, and their cooccurrence can lead to further forms of violence [11]; parental maltreatment in childhood, for instance, is associated with experiences of dating violence in adolescence [12].

Disaster settings, whether instigated by a natural disaster or armed conflict, additionally contain unique characteristics that may lead to increased violence. During disasters, the collapse of systems of social control and policing, mass displacement, and the separation of children from caregivers can heighten the risk of sexual violence and criminality [13–15]. The social support deterioration model posits that trauma linked to experiences during the disaster event or its aftermath may disrupt family functioning and erode existent social support structures, leading to increased violence within children's established care networks [16]. Domestic or intimate partner violence within households likewise can be exacerbated or produced by the breakdown of family function [17–23]. After Hurricane Katrina, Schumacher [24] found that psychological victimization significantly increased by over ten percent for both men and women and physical violence against women doubled. Violence against women and violence against children tend to co-occur in households, and even when indirect, witnessing domestic or intimate partner violence negatively impacts children's mental health and increases their probability of perpetrating physical and sexual violence in the future [25,26].

While natural disasters and armed conflict share many underlying drivers, they may differ in how they affect violence against children. In a literature review and statistical analysis of disaster victims, Norris [27] found that survivors of armed conflict and terrorism had worse psychological outcomes than those who survived natural disasters when he pooled 160 individual samples from 29 countries. Norris' findings may imply that human response to natural disasters is distinct from that of armed conflict. Given the intersection between poor mental health and violence against children [9,28], the quantity of violence that is attributable to individual psychopathology on average would likely be higher in situations of armed conflicts than natural disasters.

Unlike violence initiated by humans, natural disasters may leave community trust intact or bolster cooperation. In some settings, natural disasters are associated with reductions in violent crime [29–31], increases in family functioning [32,33], and prosocial behavior in communities and families [34–36]. One such study on communities affected by Hurricane Andrew found that one-third of respondents reported less stress with their neighbors than before the disaster, and 90% felt that the sense of sharing had been high in the neighborhood immediately after the hurricane and one year later [37]. Multiple disaster researchers over the years have hypothesized that the pattern of altruism and community cohesion after a disaster is shaped by pre-disaster social organization [38–41]. However, armed conflict is the result of underlying social inequality and tension [42–44] and occurs within a cycle of mass violence—44% of states that experienced civil war relapse into combat within five years [45]. The starting point for armed conflict typically is a weakened social structure which may be less conducive to protecting children from violence.

Religiosity and a positive interpretation of the disaster event may similarly play a role in moderating the effect of natural disasters on violence against children. A body of research has illustrated that religiosity increases following natural disasters. A recent study of five waves of data from the World Values Study and European Values Survey in 96 countries overlaid with spatial data from natural disasters indicated that so-called "religious coping", or increased religiosity as a means of bearing an unpredictable and unbearable situation, was highly associated with earthquakes [46]. The effect of being spared from perceived "acts of God" may uniquely lead to better individual mental health and greater unity of families and communities as compared to situations of armed conflict. While a distinct pathway, the underlying mechanism is complicated in that religious coping seems to improve psychological outcomes inconsistently and solely among those with a positive outlook on their situation. In contrast, feeling "punished by a divine force" increases posttraumatic stress disorder, depressive symptoms and other psychopathology [47,48]. The difference in mental health outcomes when individuals have a positive or negative interpretation is apparent in Muslims affected by the 2005 Pakistan earthquake [49], Christians exposed to Hurricane Katrina and Rita in the United States [50,51], and Buddhists after the 2004 Indian Ocean tsunami in Sri Lanka [52]. The crux of how natural disasters may differ from armed conflict and lead to differences in violence patterns may be that individuals regardless of religious belief or affiliation can possess positive beliefs that natural disasters have greater meaning which transcends human control and action.

Despite the implications for public health, a limited body of research exists on the relationship between natural disasters and violence against children. This paper fills in a gap in the literature as the first known systematic review and meta-analysis to examine the magnitude and direction of association between natural disasters and violence against children. The review aims to analyze the existing quantitative evidence to understand how associations differed across each form of violence and assess the quality of sampling and study design, measurement, and statistical analysis.

Methods

Systematic literature review

We conducted a systematic review to identify studies that provided an estimate of the magnitude and direction of association between natural disasters and violence against children. Children were defined as individuals under the age of 18, and the definition of violence encompassed physical, emotional, and sexual violence as well as bullying, maltreatment, and interpersonal violence. Witnessing domestic or intimate partner violence were categorized as a

form of emotional violence in this review, given the indirect but harmful effect on children and its inclusion within family violence literature as a form of violence against children [26,53,54]. The specific definition of violence was extracted for each article, and we operationalized general violence terms by applying the UNICEF Hidden in Plain Sight report's [55] definitions (Table 1). The United Nations International Strategy for Disaster Reduction (UNISDR) [56] broadly defines a disaster as: "A serious disruption of the functioning of a community or society involving widespread human, material, economic or environmental losses and impacts, which exceeds the ability of the affected community or society to cope using its own resources" (p. 9). In this review, the term "natural disaster" encompasses disasters triggered by hydrometeorological, geophysical, and climatological events [57]. The category purposefully includes both slow and rapid onset disasters but excludes manmade disasters, such as nuclear failures or oil spills. We constructed the violence and children Boolean search operators by adapting terms from several other reviews [58–61]. The search strategy for Medline/PubMed is provided for reference (S3 Table).

Two authors (ICT and HTF) searched 15 academic databases for articles published between the earliest logged record and May 16, 2018 (S8 Table). We restricted articles to the English language for all geographical locations. Rayyan software for systematic reviews was used to manage returned citations, remove duplicates, and blind each author's initial screening decisions on article inclusion [62]. Each author independently screened titles and abstracts against standardized inclusion and exclusion criteria (S9 Table). Once unblinded, ICT and HTF reconciled any conflicting decisions for inclusion or exclusion (17 articles in total). The full articles were retrieved if they referenced natural disasters and violence against children in the title or abstract after reconciling any conflicting decisions with a third author (KD), if needed. We extracted key information from articles in duplicate using pilot tested forms and jointly reconciled decisions. Although ICT and HTF were not blinded to the names of the publication authors or their institutional affiliation during data extraction, this information was not examined in any way to make decisions on final article inclusion or to assess quality. ICT contacted first and last authors of included publications when they were missing key information on study design and outcome measures. One of the contacted authors provided additional bivariate estimates of the effect of the Indian Ocean tsunami on violence against children which were absent in the original publication [63].

We independently assessed study quality by using the National Institute of Health Quality Assessment Tool for Cohort and Cross-sectional and Case-Control Study Designs [64] to critically compare the risk of bias in the included studies (S5–S6 Tables). Following the Cochrane Handbook for Systematic Reviews of Interventions [65], we employed these checklists to aid in comparing study quality rather than as tools for inclusion and exclusion decisions. We furthermore reviewed quality dimensions that were important to our research question. These factors include temporality; variability in operational definitions and measurement; reporting biases and missing data; representativeness; and statistical adjustments and exclusion of moderators. ICT and HTF reviewed the score for each question within assessment tools together when

Table 1. Operational definitions of violence.

Physical violence	". . .all corporal punishment and all other forms of torture, cruel, inhuman or degrading treatment or punishment as well as physical bullying and hazing by adults or by other children"
Emotional violence	"Psychological maltreatment, mental abuse, verbal abuse and emotional abuse"
Sexual violence	". . .any sexual activities imposed by an adult on a child against which the child is entitled to protection under criminal law" or ". . .committed against a child by another child if the offender is significantly older than the victim or uses power, threat or other means of pressure"

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quality scores differed and reconciled differences in discussion—all studies were rated differently by at least one question of the assessment tools. The review process abided by the Cochrane Handbook for development and execution of the search process [65] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for reporting [66]. The review protocol was prospectively registered in PROSPERO, number: CRD42018087862, and is attached (S2 Table).

Data synthesis

We synthesized the data in a narrative form followed by generating pooled estimates of violence against children following natural disasters. Salient study characteristics were compared and contrasted, including geographic location, population of children, study design, measurement, and statistical adjustment and interaction. We applied three-level random effects models to generate pooled odds ratios (OR) for categorical violence outcomes, with 95% confidence intervals (CI). Continuous violence outcomes were not statistically synthesized due to the small sample size and limited number of studies identified. This decision builds upon recent guidance that random effects meta-analysis of continuous measures should have at least five estimates to achieve consistent statistical power [67]. A three-level random effects model or multi-level meta-analysis produces generalizable results from a limited number of studies, which was particularly warranted for this review. The model allowed for selection of more than one estimate per study, reducing second order sampling bias and increasing power [68], and the random effects reduce possible errors caused by overweighting studies with large sample sizes or by making assumptions of a common underlying population [69]. We assessed heterogeneity using Cochrane's Q statistic and employed a p-value of 0.10 to determine statistically significant heterogeneity beyond sampling bias [65]. Visual inspection of radial plots accompanied heterogeneity testing, because even when non-significant, the Q statistic has low power to detect effects. When evidence of low heterogeneity, we visually examined contour-enhanced funnel plots to determine the possible presence of publication bias.[70] Analysis was conducted using the metafor package in R v.3.3.3 [71,72].

The statistical analysis followed a set protocol, using assessments of heterogeneity to determine subsequent steps in analyses and reporting. ICT initially analyzed the pooled estimate of all forms of categorical and continuous violence respectively and proceeded to subgroup analysis of the categorical violence outcomes by violence type, unadjusted and adjusted outcome measures, studies without lifetime experiences of violence, and studies that compared pre- and post-measures of violence. Within the subgroup analysis of violence types, ICT examined the overarching categories of physical, emotional, and sexual violence as well as typologies of violence within each category, such as dating violence, when comparable across multiple studies. Emotional violence was analyzed with and without the inclusion of witnessing domestic or intimate partner violence to explore any possible differences. Continuous outcomes could not be stratified for further analysis, given the scarcity of estimates. When subgroups did not indicate excessive heterogeneity and had adequate sample size to produce robust results, ICT generated pooled estimates and examined the presence of possible publication bias in contour-enhanced funnel plots.

Results

Study characteristics and quality

A total of 11 articles met the inclusion criteria for data extraction (Fig 1). Seven of the included studies were from the United States [73–79], two were from Sri Lanka [63,80], one was from Bangladesh [81], and one was from Haiti [82]. Concurrent or recent armed conflict was solely

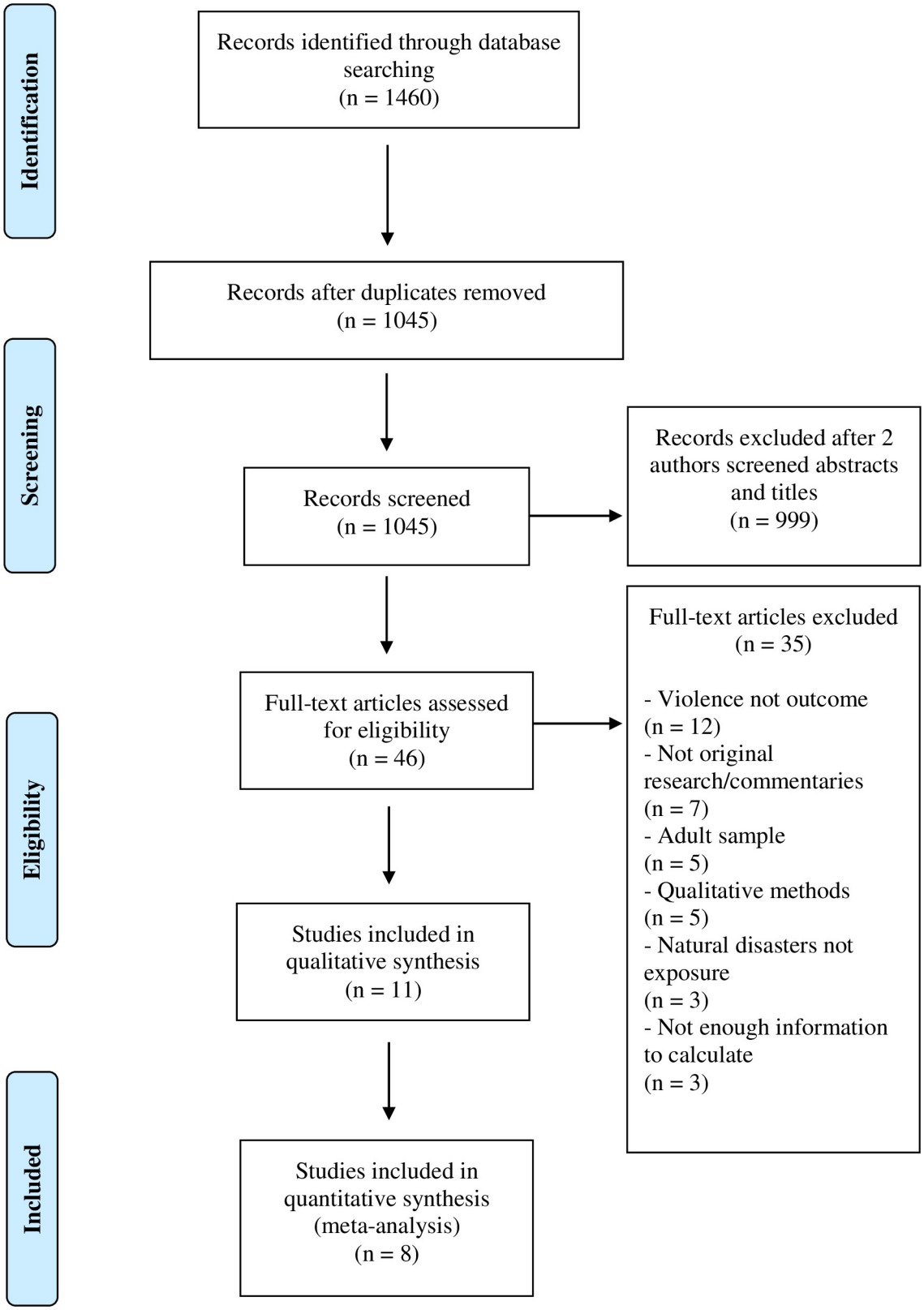

Fig 1. Flowchart of included quantitative studies.

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present in Sri Lanka [83], and Haiti had experienced recent political violence [84]. The majority of studies sampled school-going children in addition to their caregivers [63,76–80], and the age of children spanned from 0 to 18 years of age [63,73–82].

Six of the included studies were cross-sectional [63,73,78,80–82], and one study used a case-control design [76]. The remaining studies applied designs that can aid in isolating changes ascribable to natural disasters on the population level—interrupted time series design [74], pre-post quasi-experimental design with a control group [75,79], and repeat cross-sectional design [77]. Participation rates in the studies ranged considerably, from 36% [76] to 100% [63]. A lack of representativeness in sample selection decreased rigor in some studies. One of the cross-sectional studies used purposeful sampling of respondents [82], and two studies sampled controls from populations that differed in ways that may have affected the outcome and at a different timeframe from the cases [76,79].

Disaster measures

Several different disaster events were described, of which 50% were hurricanes [63,73–82]. All types of disaster events had a rapid onset, with the exception of one study that included any form of disaster exposure [73]. Exposure to disasters was often measured ecologically as being within a certain area at the time of disaster [74,75,77,79,81] or in self-report using scales [63,73,76,80]. Two articles used proxy measures of living in camps and evacuation status to measure disaster exposure [78,82]. In the case of Bangladesh, Biswas [81] combined two separate flood events that occurred in succession over a short timeframe for the categorization of exposure, and Curtis [74] examined three disasters in the United States—Hurricane Hugo, the Loma Prieta earthquake, and Hurricane Andrew—at multiple time points.

Violence measures

The most common type of violence outcome described in the articles was physical violence and corporal punishment [63,73–76,82], followed by sexual violence [63,73,74,82]. Several studies relied on administrative data or reports from caregivers which tend to underestimate violence in stable settings [85,86]. The studies varied in their practice of recording perpetrator types—some studies did not explicitly document perpetrators for all or some violence measures [73–75,77] while others employed detailed categorization [63,81]. The most commonly documented perpetrator types was parents [63,76,81,82] or intimate partners [77,78,82]. Four studies specified a timeframe in their violence measurement that followed natural disaster exposure [74–76,81]. In all other cases, the authors either measured violence as lifetime experiences, did not specify when violence occurred, or sampled at a timepoint when a proportion of the violent acts could have occurred before the disaster [63,73,77–80,82]. Violence outcomes were measured anywhere from weeks [81] to years [77] afterwards. In all but three studies, the authors used binary measures in quantifying violence as an outcome [73–75,77–79,81,82].

Statistical adjustment and interaction

Most studies statistically adjusted for some important confounders that are typical in violence studies and public health, such as gender, race/ethnicity, and the age of the child. However, it is important to note that two authors adjusted for factors that could be on the causal pathway between natural disaster exposure and experiences of violence in childhood. Biswas [81] included violence against mothers during disasters, and Catani [80] incorporated a variable on if the father or mother was deceased without specifying if the death occurred during or after the disaster. No article included moderating variables, such as social support and family functioning, community cohesion, and religious coping style and ascribed meaning [63,73–82]

Table 2. Quality characteristics of included studies.

Data source	Disaster measured before violence (y/n)	Disaster measured ecological (y/n)	Period of time between disaster and violence	Reporting	Participation rate (%)	Random sample (y/n)	Adjusted for confounders	Adjusted for factors on the casual pathway
Becker-Blease [73]	N	N	Any period during lifetime	Both	70.3%	Y	Y	N
Biswas [81]	Y	Y	1 week-1 month	Mother	65.0%	Y	Y	Y
Catani [80]	N	N	Any period during lifetime	Self	N/R	Y	Y	Y
Curtis [74]	Y	Y	3, 6, and 11 months	Administrative review	N/A	N/A	Y	N
Keenan [75]	Y	Y	~ 0–6 months and subsequent 6–21.5 months	Administrative review	N/A	N/A	Y	N
Kelley [76]	Y	N	3–7 months	Mother	36.0%	N/A	N	N/A
Madkour [77]	Both	Y	Any period during lifetime (sexual); ~ 8–20 months (physical)	Self	61.0%	Y	Y	N
Sloand [82]	N/R	N/R	12–36 months	Self	N/R	N	N	N
Sriskandarajah [63]	N	N	Any period during lifetime	Self, mother, and father	100.0%	Y	N	N
Temple [78]	N	N	Timeframe overlaps with 6 months pre and 6 months post	Self	76.0%	N/A	Y	N
Terranova [79]	N	Y	Unspecified timeframe	Self	60.0% (time 1); 62.0% (time 2)	N/A	Y	N

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(Table 2). A full description of study characteristics is found in the supplemental materials (S4 Table).

Statistical synthesis

Categorical violence outcomes. The eight studies with categorical violence outcomes included 67 estimates and had a total sample size of 332,882 individuals. Natural disasters slightly increased the overall odds of violence (pooled OR 1.38, 95% CI 1.01–1.90) (Fig 2). Statistical testing however identified substantial heterogeneity (Q (df = 66) = 252.83, $p < 0.001$). The presence of considerable heterogeneity was confirmed in a visual inspection of radial plots (S1 Fig).

Subgroup analysis. Four of the 18 subgroup analyses without evidence of excessive heterogeneity and sufficient sample size had confidence intervals that crossed 1.00 which indicates no clear directional change or evidence of effect (Table 3). Visual inspection of funnel plots did not indicate the presence of publication bias in any subgroup. The forest, radial, and funnel plots for each subgroup are included in the supplemental materials (S2–S13 Figs).

Discussion

We found no evidence of a consistent statistical association and directional influence between natural disasters and violence against children. The study characteristics and quality however tempered our conclusions. Most studies were conducted in the United States where established infrastructure and access to services may result in inherently lower violence estimates than disaster-prone areas of the world with fewer resources [73–79]. The studies tended to treat children as one group, without stratifying or statistically adjusting for subpopulations, which

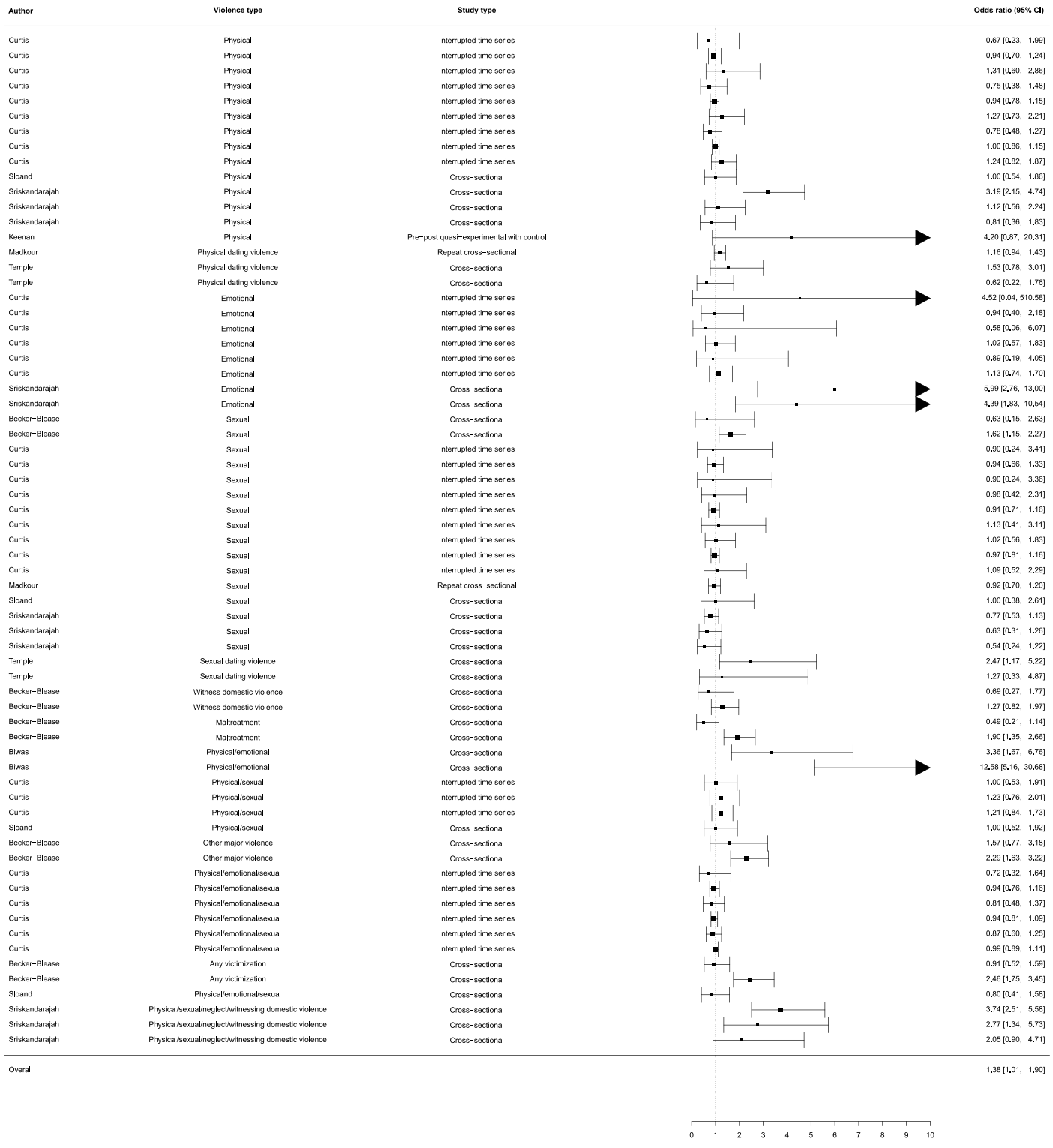

Fig 2. Forest plot of categorical violence outcomes. A three-level random effects model of the association between natural disasters and any form of violence against children. Multiple estimates were drawn from the same study if the author's name is used in more than one row. Curtis [74] analyzes three separate disasters within their article. All estimates were converted to OR for categorical violence outcomes, with 95% CIs.

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Table 3. Subgroup analysis by study design and violence outcome.

Subgroup	Number of estimates	Sample size	Pooled OR (95% CI)	95% CI	Cochrane's *Q*	*p*-value
Excluded lifetime–physical violence	14	93,878	1.05	0.91–1.20	12.307 (df = 13)	$p = 0.503$
Pre-post–all violence outcomes	36	271,001	1.01	0.90–1.15	16.754 (df = 35)	$p = 0.996$
Pre-post–physical violence	11	92,752	1.05	0.89–1.24	10.033 (df = 10)	$p = 0.438$
Pre-post–sexual violence	10	59,867	0.95	0.85–1.06	0.524 (df = 9)	$p = 1.000$

All subgroup analyses are for categorical violence outcomes

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possibly masked elevated violence among certain groups of highly vulnerable children [87–89]. In particular, sampling children in schools likely resulted in violence estimates that were lower than those for out-of-school children who may be more vulnerable to violence [90,91]. Low-income families that are evacuated are less likely to return to disaster-affected areas [92], leading to samples that potentially missed a group of children who may have higher levels of violence [89]. Cross-sectional surveys additionally cannot identify changes from pre-disaster estimates of violence, and low participation rates and non-representative sampling methods frequently lead to biases.

This review adds to the body of knowledge on violence against children in disaster settings. No other review has expressly examined natural disasters and violence against children [21,93,94]. In a systematic review on violence against children [93] and another systematic review of gender-based violence [21], both reviews were almost entirely composed of violence studies in situations of armed conflict. This review distinguishes natural disasters from armed conflict to explore differences in quantitative effects by violence type, measurement, and study design. Past reviews have expressed that violence trends were impossible to determine but were likely high on the population level [21,93]. Our findings may indicate that natural disasters have a unique pattern of violence from that of armed conflict which merits further study.

Our ability to draw firm conclusions was limited by the measurement and analysis methods of the included studies. The most common metric for measuring natural disaster exposure was geographic proximity which, depending on disaster type and severity, can be a weak proxy for direct exposure since not all people within a physical area are necessarily exposed [74,75,77,79,81]. Few studies used exactly comparable violence definitions. The reliance on caregiver reports and administrative data likely would have underestimated the measurement of violence in many studies [74–76,81], and past research has shown that child sexual violence rates may be greater than 30 times higher [85], and physical abuse rates may be more than 75 times higher in self-reporting [86]. The measurement of violence was restricted to acts committed by a limited range of actors and most commonly parents [63,76–79,81]. While the restriction often matched the goals of the individual study, the results would likely underestimate the total amount of violence that children experienced. Meaningful associations may have been diluted by the lack of establishment of a clear temporal order between natural disasters and violence and by the measurement of violence multiple years after the disaster in some studies. The reliance on binary variables for measuring violence outcomes possibly missed subtle changes in modeling the effect of natural disaster exposure. Finally, in some studies, the statistical adjustment for variables on the causal pathway could have decreased the estimated association between natural disasters and violence, and the exclusion of moderating factors could have led to inaccuracies in measurement.

The pooled estimate of combined violence outcomes indicated substantial heterogeneity, and subgroup analysis did not provide a clear explanation of the source of the variability. The

majority of the heterogeneity was likely due to the inconsistencies in the methodologies of the included studies. The four subgroups that were fully analyzed similarly indicated no clear change in the direction of the association between natural disasters and violence against children. Publication bias was unlikely in the subgroup analyses. The funnel plots exhibited an absence of studies with low precision—small sample sizes and large variance—but they were symmetrical and did not have patterns of missingness for negative or positive results. This finding implies that factors other than publication bias, such as variability in study quality, are more likely present [95].

Strengths and limitations

This review searched global databases to produce the first systematic review and meta-analysis on the relationship between natural disasters and violence against children. Despite the comprehensiveness and statistical rigor of this review, it has several limitations. The main limitation is that our search concentrated on health and social science databases. The relationship between violence against children and natural disasters cross-cuts multiple disciplines, and relevant articles may have appeared in criminology, social work, or disaster response databases beyond the scope of our search strategy. We however attempted to search a multitude of prominent databases where articles on violence would likely be referenced. Additionally, it is possible that we missed relevant publications due to the variable terminology used to describe violence, populations of children, or natural disasters. A further limitation is that we did not include non-English sources. We therefore potentially did not identify relevant studies reported in non-English settings where natural disasters frequently occur.

Implications

Few studies have measured violence against children following natural disasters, and this review is the first systematic attempt to quantify and understand the underlying relationship. At various junctures, the World Health Organization (WHO) and academic literature have called for more evidence on this topic [74,96,97]. Despite the appeals, quantitative studies on violence against children in the aftermath of both natural disasters and armed conflict remain scarce and continue to suffer from quality issues [21,93]. At minimum, more high-quality research is needed to understand how natural disasters are associated with violence against children and to distinguish how the relationship may differ from situations of armed conflict.

Our findings challenge assumptions that violence will be escalated above normal levels following a natural disaster. Violence against children is high globally regardless of the occurrence of a disaster, and services for children are always critical in all settings [98,99]. However, we cannot confidently conclude that natural disasters increase the level and severity of violence against children above that found in non-disaster settings, based on the scope and quality of the available evidence. We do not clearly understand which types of violence are most likely to increase, for which groups of children, and in what contexts following natural disasters. These differences may necessitate specialized services to certain children at specific times. We may need to tailor interventions differently than our current practices to maximize our effort.

We are entering a time when global climate change is spurring increased and more severe natural disasters [1–3] and affecting a greater number of people globally [4,5]. In particular, lower- and middle-income countries are disproportionately affected by natural disasters—they represent 11% of the population exposed to natural disasters but 53% of the casualties [100]. Future natural disasters may therefore occur in places where health and protection systems are less developed [101,102], and the sudden influx of people needing services and increased barriers to service provision are likely to further burden overstretched healthcare providers and

social workers [103,104]. It is imperative that we understand the fundamental relationship between natural disasters and violence against children to create effective policies and to allocate limited resources in health and child protection systems based on evidence.

We identified several areas for recommended future research in this review. More research is needed about lower- and middle-income countries that face disproportionate vulnerabilities to natural disasters [100]. Contextual understanding of the effect of past or concurrent armed conflict, political violence, and seasonal and successive disaster events on violence against children would aid in isolating and differentiating natural disasters from other environmental disruptions. In addition, all of the natural disasters in this review had a rapid onset. Investment in better understanding slow-onset disasters is merited. Future research should explore factors that are protective and moderate violence in natural disaster contexts, as these factors may be distinct from those found in man-made disasters. We have reason to consider social support and family functioning, community cohesion, and religious coping style and ascribed meaning as starting points [32,37,51,105,106].

Conclusions

More high-quality and nuanced research is needed on the association between natural disasters and violence. Without scientifically examining the relationship in a rigorous manner, we negate the possibility of understanding the effect of natural disasters on violence against children and in identifying populations that are most at risk for specific forms of violence. In a limited funding environment with multiple priorities, targeting effective interventions to the most vulnerable populations is essential. As natural disasters increasingly affect human populations, we must better understand the underlying relationship with violence to protect children and improve human health.

Supporting information

S1 Table. PRISMA checklist.
(DOCX)

S2 Table. Review protocol.
(DOCX)

S3 Table. Medline search strategy.
(DOCX)

S4 Table. Descriptive analysis of included studies.
(DOCX)

S5 Table. Risk of bias results for cross-sectional and cohort studies.
(DOCX)

S6 Table. Risk of bias results for case-control studies.
(DOCX)

S7 Table. Data used in R for meta-analysis.
(XLSX)

S8 Table. Data repositories searched.
(DOCX)

S9 Table. Inclusion and exclusion criteria.
(DOCX)

S1 Fig. All categorical violence outcomes radial plot.
(EPS)

S2 Fig. Physical violence without lifetime measures forest plot.
(EPS)

S3 Fig. All violence outcomes with pre-post design forest plot.
(EPS)

S4 Fig. Physical violence with pre-post design forest plot.
(EPS)

S5 Fig. Sexual violence with pre-post design forest plot.
(EPS)

S6 Fig. Physical violence without lifetime measures radial plot.
(EPS)

S7 Fig. All violence outcomes with pre-post design radial plot.
(EPS)

S8 Fig. Physical violence with pre-post design radial plot.
(EPS)

S9 Fig. Sexual violence with pre-post design radial plot.
(EPS)

S10 Fig. Physical violence without lifetime measures funnel plot.
(EPS)

S11 Fig. All violence outcomes with pre-post design funnel plot.
(EPS)

S12 Fig. Physical violence with pre-post design funnel plot.
(EPS)

S13 Fig. Sexual violence with pre-post design funnel plot.
(EPS)

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Author Contributions

Conceptualization: Ilan Cerna-Turoff.

Data curation: Ilan Cerna-Turoff.

Formal analysis: Ilan Cerna-Turoff, Hanna-Tina Fischer.

Investigation: Ilan Cerna-Turoff.

Methodology: Ilan Cerna-Turoff, Karen Devries.

Project administration: Ilan Cerna-Turoff, Susannah Mayhew.

Resources: Ilan Cerna-Turoff.

Software: Ilan Cerna-Turoff.

Supervision: Ilan Cerna-Turoff.

Validation: Ilan Cerna-Turoff.

Visualization: Ilan Cerna-Turoff.

Writing – original draft: Ilan Cerna-Turoff.

Writing – review & editing: Hanna-Tina Fischer, Susannah Mayhew, Karen Devries.

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CHAPTER 6. RESEARCH PAPER 2 - PATHWAYS TO VIOLENCE

In response to the inconclusive results in the previous chapter, I further explored what potential pathways to violence might exist after a natural disaster. This chapter presents a systematic review to synthesize evidence on pathways between natural disasters and violence against children (Objective 2). Unlike the background literature described in Chapter 2, which was purposefully expansive, this chapter identifies complete pathways from natural disasters to violence against children that are currently identified in the literature.

A draft of this chapter was submitted to BioMed Central Public Health and is under peer review. The journal is open access under a creative commons license (CC BY 4.0 - https://creativecommons.org/licenses/by/4.0/). The supplementary materials referenced in the manuscript are provided at the end of the thesis as Appendix C.

London School of Hygiene & Tropical Medicine
Keppel Street, London WC1E 7HT

T: +44 (0)20 7299 4646
F: +44 (0)20 7299 4656
www.lshtm.ac.uk

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Surname/Family Name	Cerna-Turoff		
Thesis Title	Understanding and measuring the complex relationship between natural disasters and violence against children		
Primary Supervisor	Dr Susannah Mayhew		

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For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	I conceptualized and designed the review; screened the articles; analyzed the data; and drafted the manuscript.

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The pathways between natural disasters and violence against children: a systematic review of humanitarian literature

Ilan Cerna-Turoff[1]; Hanna-Tina Fischer[2]; Hani Mansourian[2]; Susannah Mayhew[1]

Affiliation of authors:

[1] Global Health and Development, London School of Hygiene and Tropical Medicine, London, United Kingdom

[2] Mailman School of Public Health, Columbia University, New York City, New York, United States

Abstract

Background

A comprehensive understanding of how natural disasters lead to violence against children is essential in designing effective prevention. Although natural disasters increasingly affect human populations, little is understood about how natural disasters lead to violence against children. We systematically reviewed academic and grey literature to document the pathways between natural disasters and violence against children.

Methods

We searched 15 academic databases and six grey literature repositories from the earliest date of publication to May 16, 2018. In addition, we solicited literature from humanitarian agencies globally. Academic and grey literature that presented original findings on the pathways between natural disasters and violence against children was included.

Findings

We identified 6276 unduplicated articles and reports. Nine academic articles and seventeen grey literature reports met the inclusion criteria. The literature outlined five pathways between natural disasters and violence, including: (i) environmentally induced changes in supervision, accompaniment, and child separation; (ii) transgression of social norms in post-disaster behavior; (iii) economic stress; (iv) negative coping with stress; and (v) insecure shelter and living conditions.

Implications

Humanitarian agencies should target the identified pathways to create effective violence prevention programs after natural disasters. The positive coping strategies within certain affected families and communities can be leveraged in programmatic design to protect

children from violence, presenting opportunities that may differ from man-made disasters, such as situations of armed conflict. Humanitarian agencies would benefit from systematic documentation of all possible pathways to a high-quality standard in improving the effectiveness of future programming.

Keywords

Children; violence; child protection; natural disaster; humanitarian crisis; emergency

Introduction

Natural and man-made disasters disrupt services and societal structures, displace populations, and lead to a high likelihood of trauma [255, 256, 454, 455]. In particular, children are considered a priority population because of their vulnerability to experiencing violence in these settings [456]. Natural disasters occupy an equivalent status to man-made disasters within humanitarian response frameworks and scholarship, but much less is known about how they may lead to violence against children [25, 383, 457, 458]. Humanitarian agencies currently implement child protection programming after natural and man-made disasters with similar intervention structures, timing for delivery of services, and target populations under the theorical assumption that they produce identical manifestations of violence against children. Structural elements and the affected population's interpretation of the events may be distinct, however, and as a result, the pathways to violence against children may differ. One of the few studies that modelled family violence among those affected by the Sri Lankan civil war and the 2004 Indian Ocean Tsunami together found that war exposure predicted violence against children (β = 0.34, $p < 0.001$), while tsunami exposure acted in the reverse (β = -0.16, $p < 0.01$) [100]. During conflict, the presence of armed actors poses a direct risk of violence which often does not exist during natural disasters in the same manner. Communities and

individuals, furthermore, can prepare for certain types of natural disasters, such as typhoons or flooding, that reoccur annually. Indigenous coping mechanisms for managing food supplies and providing social support may reduce the negative impact on human populations [459]. While man-made disasters may erode a sense of trust in one's community and society, a growing body of psychological and sociological research suggests that natural disasters can improve functioning within families and lead to greater sense of community cohesion and altruism [294, 404, 460–463]. Spatial temporal analysis in Chile, for instance, found that social cohesion on the community level increased after large-scale earthquakes and faded over time as conditions normalized [422]. The differential meanings that affected populations ascribe to natural and man-made disasters seem to influence individuals' reactions. As a 2014 psychological study on risk judgement illustrates, when people perceive the cause of something as "natural", they are less likely to judge it as severely as a disaster caused by man [464]. In other words, people respond more negatively to armed conflict and political violence than natural disasters, because they perceive natural disasters as outside of human control. This trend is further corroborated in a large-scale review which found that survivors of armed conflict and terrorism had worse mental health outcomes than survivors of natural disasters in samples from 29 countries over two decades [256]. Negative perception and accompanying poor mental health responses may relate to an increased risk of violence against children, as indicated in past studies [266–268].

Natural disasters are increasingly affecting a larger segment of the world's population [465]. In 2017, the Centre for Research on the Epidemiology of Disasters (CRED) estimated that natural disasters affected 96 million people, and the United Nations Children's Fund (UNICEF) estimated that natural disasters and other forms of disasters affected approximately 350 million children [466, 467]. Displacement can be considered

an indication of extreme exposure to a disaster event. Between 2008 to 2016, an average of 25.3 million people were displaced by natural disasters each year, and although predictions vary, it is estimated that by 2050 extreme weather events will result in forced displacement of over 200 million people [96, 97]. The International Displacement Monitoring Centre (IDMC) estimates that natural disasters caused 18.8 million new displacements in 2017, while armed conflict led to 11.8 million new displacements [468].

Increasing our understanding of the pathways between natural disasters and violence against children is essential in designing effective violence prevention and response programs. Humanitarian agencies have a mandate to provide evidence-based services to prevent any unforeseen harm to children. Identifying the junctures at which one can intervene and the mechanisms by which violence occurs facilitate better tailoring of protection programming. Elsewhere, we provided a meta-analysis of quantitative research which showed that there is inconclusive evidence of a direct association between natural disasters and violence against children but noted the need for more nuanced research to offer a richer understanding of pathways to violence and inform humanitarian response [453]. This paper provides a systematic review of academic and grey literature to deepen the understanding of the pathways between natural disasters and violence against children.

Methods

Search strategy

The first and second author systematically reviewed academic and grey literature that presented original information on the pathways between natural disasters and violence against children. Grey literature in the humanitarian field tends to take the form of reports based upon rapid appraisals of the needs of the affected community, regular monitoring

of programmatic activities, and evaluations of gaps in service provision. We operationalized the definition of children as people under 18 years of age and the definition of physical, emotional, and sexual violence using UNICEF's *Hidden in Plain Sight* report (refer to Table 5) [41]. Violence prevention and response are components of the field of child protection which additionally addresses broader issues of neglect, exploitation, and abuse [383]. Natural disasters can be defined as originating from environmental factors that are not directly caused by man; however, we recognize that they may have distal roots related to human behavior and alterations of the physical environment [107]. In applying the conventions of disaster response, we did not examine disasters that were directly man-made [10]. We included both slow and sudden-onset natural disasters in this review.

Table 5. Operational definitions of violence

Form of violence	Definition
Physical violence	"…all corporal punishment and all other forms of torture, cruel, inhuman or degrading treatment or punishment as well as physical bullying and hazing by adults or by other children"
Emotional violence	"Psychological maltreatment, mental abuse, verbal abuse and emotional abuse"
Sexual violence	"…any sexual activities imposed by an adult on a child against which the child is entitled to protection under criminal law" or "…committed against a child by

	another child if the offender is significantly older than the victim or uses power, threat or other means of pressure”

United Nations Children’s Fund [41], p. 4

We searched 15 academic databases and six grey literature repositories from the earliest date of publication to May 16, 2018 (Appendix 1). All searches were restricted to the English language for natural disasters globally. The search strategy for academic databases has been published elsewhere as part of a related systematic review on the relationship between natural disasters and violence against children [453]. We searched all uploaded reports, assessments, or evaluations in grey literature databases, given the variability of search engine structure. We solicited additional literature from twelve experts within agencies that lead global child protection responses in humanitarian contexts. Focal points whose area of work includes child protection from UNICEF, United Nations High Commissioner for Refugees (UNHCR), International Organization for Migration (IOM), United Nations Population Fund (UNFPA), and International Federation of Red Cross and Red Crescent Societies (IFRC) were contacted. UNICEF focal points, in turn, solicited recommendations for literature from all Child Protection Coordinators and Information Management Officers (IMOs) worldwide. The Child Protection Area of Responsibility (CP AoR)—the global coordination body for child protection in humanitarian contexts led by UNICEF—and IFRC provided supplemental grey literature materials which were not uploaded onto online repositories.

Selection and analysis

After removal of duplicates, the first and second author independently screened the titles and abstracts of the academic literature and the titles and abstracts, executive summaries,

and table of contents of the grey literature, as per published guidelines [469]. All academic articles and grey literature reports that mentioned both violence against children and natural disasters in these sections were maintained for full text review, after jointly reconciling any conflicting decisions. We used standardized inclusion and exclusion criteria for our decision making in screening. A key inclusion criterion was that the source had to contain original evidence on the pathways between natural disasters and violence against children.

Table 6. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
1. Natural disasters are the exposure of interest 2. The outcome measure is any form of violence, including physical, emotional, or sexual violence, bullying, maltreatment, interpersonal violence, or witnessing domestic violence (DV) 3. The person who experiences the violence is a child or adolescents under 18 4. Original research identifying the pathway between natural disasters and violence against children	1. Gang violence, female genital mutilation (FGM), neglect, or child labor, exploitation, trafficking, or marriage as outcomes 2. Editorials, policy reviews or general reports that do not introduce new evidence 3. Conference abstracts 4. Secondary reviews of literature

5. Academic or grey literature	

The full text for 16 grey literature reports was not publicly posted in which case, ICT attempted to contact the publication authors directly. No authors responded to furnish full texts. We double extracted topical information on the disaster and violence context and methodological information about the study design and analysis. We did not place any predetermined criteria on pathway structure. We extracted detailed information describing how natural disasters led to violence from qualitative articles and the quantitative relationships between variables indicated in modeling and pathway analyses. If sources included acts of violence against adults, we extracted information on pathways to violence for those below 18 years of age to abide by our operational definition of children. All information extracted was jointly reconciled by the first and second author. We compared information and iteratively sorted it into overarching pathway categories. This process relied upon both authors' experience in the humanitarian field which aided in understanding the lines of demarcation between pathways.

Quality appraisal

We used the Critical Appraisal Skills Programme's Qualitative Research Checklist and the National Institute of Health Quality Assessment Tools for Cohort and Cross-sectional and Case-Control Study Designs as means of critical comparison [470, 471]. In the case of mixed-methods studies, we evaluated the qualitative and quantitative components separately. We positively scored the appropriateness of the article or report's methodology if it matched at least one of its outlined aims and objectives. The final question in the Critical Appraisal checklist is a subjective determination of value. We rated value based on provision of nuanced information and practical recommendations for stakeholders. The research team used these tools in comparing quality, rather than in

inclusion and exclusion decisions, which is in-line with the Cochrane Handbook's guidance for systematic reviews [472]. The review results are presented in a narrative synthesis following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [473]. The PRISMA checklist is included in the appendices for reference (Appendix 2).

Results

Characteristics of academic and grey literature

We identified a total of 1045 unique academic articles and 5231 grey literature reports (refer to Figure 5). Nine academic articles and seventeen grey literature reports matched the criteria for inclusion. Amongst the academic articles, five of the nine studies utilized qualitative methods and three applied quantitative methods. Both qualitative and quantitative findings were included when the study employed mixed-methods. All grey literature used qualitative methodologies.

Two of the academic articles described flooding events in 1998 and 2007 in Bangladesh [242, 474], and three publications described four separate disasters in the United States [66, 152, 475]. The remaining articles focused on Haiti, Nepal, and Sri Lanka—two focused on devastating earthquakes [311, 476], and two described the 2004 Indian Ocean Tsunami [100, 477]. The grey literature described disasters in a range of regions, with the greatest number occurring in Asia and the Pacific and a single report from the Americas describing the aftermath of the 2010 Haitian earthquake [478, 479, 488, 480–487]. Drought and extreme tropical storms in the form of typhoons, cyclones, or hurricanes were the most common disasters in the grey literature [478, 479, 493, 494, 480, 484, 486, 488–492]. A single report incorporated a temporal element in explaining pathways to violence; in the Lao People's Democratic Republic, commonly known as "Laos",

adolescent and adult respondents mentioned that the lack of safety and surveillance and economic hardship in the first one to two weeks after the disaster led to spikes in violence against children that returned to normal levels afterwards [479]. An interview with a Child Protective Services provider as part of a mixed methods study indicated that a possible reverse pattern existed in the United States. Frustration grew over time due to the slow pace of recovery and led to increases in violence against children. The amount of time was not specified, however [66]. Two of the five countries in the academic articles and three of the thirteen countries in the grey literature were concurrently experiencing armed conflict or some other form of man-made disaster [495].

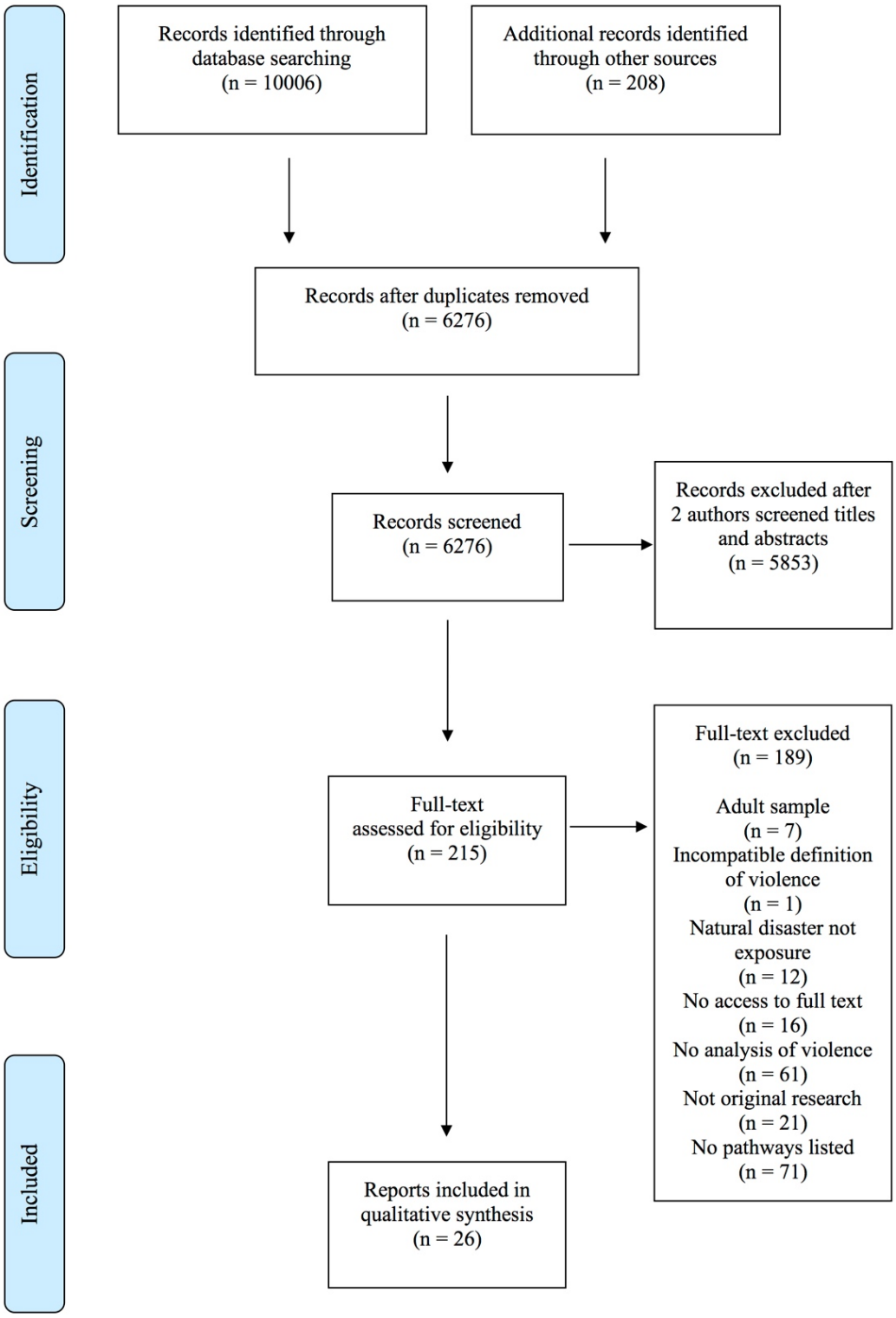


Figure 5. PRISMA flowchart of included sources

Sexual violence was documented in most academic articles, barring Biswas et al. [474] which described physical and emotional violence committed by mothers and fathers against children and Terranova et al. [475] and Scott et al. [152] which described physical and emotional bullying behaviors among children. In the grey literature, all but three reports contained information on pathways to sexual violence [480, 483, 486]. Physical violence was the second most common form of violence [478, 480, 481, 484–486, 492, 493]. Emotional violence and all forms of bullying were underrepresented in the grey literature [482, 483, 494]. The academic literature mainly collected information on children below the age of 18. One article did not specify the exact age range among children under 18 [477], and another recruited respondents as old as 19 years [242]. The grey literature often did not specify the age range of children or used variable age ranges, with some individuals as old as twenty categorized as "children" [478–480, 484, 486, 490, 492–494].

Quality of evidence gathering, analysis, and reporting practices

The academic articles and grey literature reports exhibited variable levels of quality in their evidence gathering and reporting practices. Six academic articles relied upon qualitative semi-structured interviews with affected individuals and key informants [66, 242, 311, 474, 476, 477]. The four academic articles that applied quantitative methods administered surveys to households or to school-going children and their parents [100, 152, 474, 475]. Overall, the included academic studies appropriately analyzed the data. One article, however, attempted to infer quantitative information on incidence from qualitative interviews [477]. Within the body of qualitative academic publications, several unclearly reported on their data collection methods and did not distinguish between the authors' views and those of the respondents. Quotes in some instances were extracted without any description of how the information was generated, and on the other

extreme, information was presented without directly citing respondents in a clear manner [474, 476, 477]. In contrast, Rashid and Michaud's [242] study of adolescent girls was an example of a nuanced description of violence-related issues after floods in Bangladesh. The study provided explicit analysis of positionality, as Rashid discussed her insider-outsider status as a Bangladeshi who was raised abroad and Michaud's Canadian identity. Amongst the quantitative academic publications, a major threat of bias came from sampling choices. Several studies used samples that were not representative of the entire affected population of children but interpreted them as such. School-going children formed a key group of respondents, but the pathways to violence among those that have access to education may differ from those that do not attend school [100, 152, 475, 496].

The grey literature applied a combination of qualitative methodologies, including interviews with directly affected communities, focus group discussions (FGD), direct observation, and key informant interviews. All studies appropriately sought out both female and male respondents to capture gendered perspectives of pathways and separated FGD by gender. Notably, most of the grey literature directly engaged children as respondents, and two reports partitioned children into separate age ranges [482, 493]. The chosen methodologies, however, were not described in detail, and reporting was minimal at best. The grey literature treated the evidence as if it was representative of the entire affected population and did not explore limitations or differences in perspectives. Some reports did not include an abstract or overview, while others did not provide complete information on the research questions, methodologies, and findings. Within the main body of text, only one report provided details on how the authors synthesized evidence [482]. The presentation of the findings on pathways was similarly presented without sufficient depth. It was often impossible to ascertain the extent to which the description of the pathway constituted the opinion of the respondents or a secondary interpretation

by the publication authors. The extent to which local researchers led the production of knowledge likewise was challenging to assess. Four reports indicated that they were written or led by international researchers from outside of the disaster country [479, 481, 487, 491]; two others implied that international teams had a significant role in the production of knowledge [478, 488]; and seven additional reports were spearheaded by the national arm of an international non-governmental organization [482–484, 490, 492–494]. A governmental agency was the first author for three reports from Tonga, Zimbabwe, and Bangladesh [480, 485, 489]. The full risk of bias scoring for included sources is found in Appendix 3.

Table 7. Included academic and grey literature

					Selected quality markers				
Data source	Country and disaster	Violence type	Age range of children	Co-occurrence of a man-made disaster	Appropriate methodological design	Relationship between researcher and respondents considered	Ethical issues considered	Data analysis rigorous	Risk of bias quality score
Academic literature									
Biswas et al. [474]	Bangladesh; 2007 floods	Physical; emotional	Under 18	N	Y	N	N	N (qualitative) Y (quantitative)	4 (qualitative) 8 (quantitative)

Catani et al. [100]	Sri Lanka; 2004 Indian Ocean Tsunami	Physical; emotional; sexual	9 to 15	Y	Y	N	N	Y	6 (quantitative)
Curtis et al. [66]	United States; 1989 Hurricane Hugo; 1989 Loma Prieta Earthquake; 1992 Hurricane Andrew	Physical; emotional; sexual	Under 18	N	N	N	N	N	1 (qualitative)

Davis and Bookey [476]	Haiti; 2010 earthquake	Sexual	5 to 18	N	Y	N	N	N	2 (qualitative)
Fisher [477]	Sri Lanka; 2004 Indian Ocean Tsunami	Sexual	Not reported	N	N	Not reported	Not reported	Not reported	3 (qualitative)
Rashid and Michaud [242]	Bangladesh; 1998 floods	Sexual	15 to 18	Y	Y	Y	Y	Y	8 (qualitative)

Scott et al. [152]	United States; 2005 Hurricane Katrina	Emotional (bullying)	8 to 15	N	Y	N	Y	Y	9 (quantitative)
Standing et al. [311]	Nepal; 2015 earthquake	Sexual	Under 18	N	Y	N	N	N	3 (qualitative)
Terranova et al. [475]	United States; 2005 Hurricane Katrina	Physical and emotional (bullying)	Fifth graders (mean: age 10)	N	Y	N	N	Y	8 (quantitative)

Grey literature									
CARE Ethiopia [490]	Ethiopia; 2015 to present drought	Sexual	Not reported	N	Y	N	N	N	5 (qualitative)
Child Protection Sub-Cluster [478]	Philippines; 2012 Typhoon Bopha	Physical - younger children; sexual - in households	Not reported	Y	N	Not reported	Not reported	N	5 (qualitative)
Civil Protection Zimbabwe [489]	Zimbabwe; 2017 Tropical	Sexual (particularly ages 5 to 18)	Under 18	N	Y	N	N	N	5 (qualitative)

	Cyclone Dineo								
Government of Bangladesh and Humanitarian Coordination Task Team of Bangladesh [485]	Bangladesh; 2017 floods	Physical; sexual	Under 18	N	Y	N	N	Y	8 (qualitative)
International Federation of Red Cross and	Laos, Indonesia, and Philippines;	Sexual	Not reported	Y (Philippines)	Y	N	N	Y	7 (qualitative)

Red Crescent Societies [479]	2016 Oudomxay Floods and 2009 Typhoon Ketsana in Sekong; 2016 Aceh Earthquake and 2016 Aceh and Bima Flash Floods; 2013 Typhoon Haiyan

Jinks and Komenji [486]	Papua New Guinea; 2016 frost and drought	Physical	Not reported	N	Not reported	Not reported	Not reported	N	1 (qualitative)
Ministry of International Affairs of the Government of the Kingdom of Tonga and Pacific Humanitarian Cluster [480]	Tonga; 2014 Cyclone Ian	Physical	Not reported	N	Y	Not reported	Not reported	Not reported	6 (qualitative)

Oxfam and CARE Ethiopia [494]	Ethiopia; 2015 to present drought	Emotional; sexual	Not reported	N	Y	N	N	Y	8 (qualitative)
People in Need Czech Republic [481]	Nepal; 2015 earthquake	Physical; sexual	Under 18	N	Y	N	N	N	6 (qualitative)
People in Need Czech Republic [487]	Nepal; 2015 earthquake	Sexual	School-aged girls, grades 6 to 10	N	Y	N	N	Y	6 (qualitative)

Withers and Dalal [482]	Nepal; 2015 earthquake	Emotional; sexual	8 to12 and 13 to 18	N	Y	N	N	Y	8 (qualitative)
Polack [491]	Kenya; 2006 to 2009 drought	Sexual	Under 18	Y	Y	N	N	N	4 (qualitative)
Save the Children [483]	Mongolia; 2016 to 2017 dzud	Bullying	6 to 16 in FGD and not reported	N	Y	N	N	N	4 (qualitative)
Save the Children	Somalia; 2015 to	Physical; sexual	Not reported	Y	Y	N	N	N	6 (qualitative)

[492]	present drought								
Save the Children [484]	Papua New Guinea; 2014 to 2015 drought	Physical; sexual	Not reported	N	Y	N	N	N	6 (qualitative)
Save the Children [493]	Kenya; 2011 to 2012 East Africa drought	Physical; sexual	10 to 11 and 12 to 16 in FGD and not reported	Y	Y	N	N	N	4 (qualitative)

United Nations Population Fund and Ministère à la Condition féminine et aux Droits des femmes [488]	Haiti; 2016 Hurricane Matthew	Sexual	15 to 18	N	Y	Not reported	N	N	4 (qualitative)

Y = Yes and N = No. In the case that a dataset included people over the age of 18, the age range indicates the viable sample of respondents under the age of 18 that was utilized for analysis. The Uppsala Conflict Data Program (https://ucdp.uu.se/) was referenced to confirm the presence of man-made disasters in the same country, region, and timeframe.

Pathways between natural disasters and violence against children

The pathways identified in the literature were thematically organized into five categories: (i) environmentally induced changes in supervision, accompaniment, and child separation; (ii) transgression of social norms in post-disaster behavior; (iii) economic stress; (iv) negative coping with stress; and (v) insecure shelter and living conditions.

Environmentally induced changes in supervision, accompaniment, and child separation

Respondents identified changes in caregiver and children's travel and movement following natural disasters which produced new patterns of accompaniment and separation. In some settings, the changes increased violence, and in others, they were protective. In Ethiopia, for instance, two grey literature reports identified new gendered patterns of movement that increased sexual violence risk. During the drought, girls ventured further away from their homes to find water or were left in their household alone for long time periods while their mothers fetched water. As water sources became scarcer, girls began to collect water at night to avoid queues during the day. Male family members likewise were forced to migrate longer distances to find paid work and tend to their cattle which left female members of the household alone [490, 494]. Each of these changes—movement to isolated locations, being left unaccompanied in the home, and travel in darkness—increased the risk of violence against girls. Findings from droughts in Kenya and Somalia similarly reinforced that girls were at risk of sexual violence when they searched for food, firewood, and water or travelled for work, particularly in the early morning or evening [491, 492]. Street harassment was common, and although respondents admitted that it had existed prior, "It was more scary during the floods because there were more *mastaans* [hoodlums] and *goondahs* [thugs] hanging about" (Rashid and Michaud [242], p. 62). This increase in unknown men congregating in a new

shared space created a situation ripe for opportunistic sexual violence. Women and girls increasingly relied on physical proximity to their former neighbors and communities or on sending girls to stay with distant family members as a means of protection. Boys experienced distinct forms of violence as they travelled. Respondents believed that boys who moved to towns and away from their homes in Somalia during a drought faced heighted risk of physical violence from employers and other adults [492]. Violence between children additionally increased in some settings. In Mongolia, adults from herder communities spent a greater amount of time tending to cattle during extreme winter conditions which led to minimal supervision and increases in bullying from peers [483].

Permanent separation from friends and adult caregivers produced some of the greatest ongoing sexual violence risks, especially for girls. Girls who lived alone in camps after the 2010 Haitian earthquake and after the 2015 Nepal earthquake faced sexual violence risk from strangers, as spaces were often transitory and lacked strong systems of policing and social control [311, 476]. Respondents in one study believed that girls whose mothers died during the 2004 Indian Ocean Tsunami in Sri Lanka were at risk of sexual violence within their homes from fathers, brothers, or other male family members. Risk was attributed to the isolation of girls with male family members and the reduced ability of adult members of the household to have sex, given the lack of privacy [477]. The provided reasons are proximal, however, and do not analyze problematic aspects of gender norms which dictate that spaces must be gender segregated to prevent sexual violence and that men and boys cannot control sexual desires, notwithstanding the societal taboo of incest.

In contrast, a series of grey literature reports described how changes in travel and movement protected children from violence. After the 2015 Nepal earthquake, respondents mentioned that parents became more protective of their children and

restricted their mobility, leading to less violence from strangers [482]. The reason why a shift occurred in parenting and how it intersected with parents' past disaster experiences was not explored. In a report on a Kenyan drought, some respondents believed that sexual violence against girls decreased, because girls who would have faced risks while herding were now either in school or working as domestic helpers since the cattle had largely died [493]. Two grey literature reports from the Pacific region highlighted culturally-specific coping mechanisms that prevented violence after natural disasters [480, 484]. Although not dissected further, communities in Tonga outlined that traditional values led to the creation of community safety nets after a cyclone so that adults in the communities watched children outside of their homes and prevented any acts of violence [480]. Respondents in Papua New Guinea similarly mentioned that joint family structures were protective against sexual violence during a drought, because young children were not left alone, and children travelled long distances in groups to fetch water [484].

Transgression of social norms in post-disaster behavior

Natural disasters lead to structural changes, and individuals may adapt their behaviors in ways that transgress social norms. A clash of meaning exists when individuals interpret behavior by what is deemed "normal" in stable settings. This signification of behaviors as transgressive may cause individuals to act out in violent ways against children. In Nepal, it is traditionally believed that women and girls are "unclean" when they menstruate, but girls had limited access to basic feminine hygiene products after displacement from flooding. They commonly slept outside of their tents to avoid "polluting" the household and as a result, experienced sexual violence from strangers [311]. Similarly, in Bangladesh after floods, adolescent girls mentioned that they faced sexual harassment *en route* to work, because by wading through flood waters, it caused the fabric of their saris to cling to their bodies in a socially unacceptable manner [242].

In the Afar region of Ethiopia, some communities practice a tradition known as *mira*, or entitlement for men to have forced sex with women and girls while their husbands are away. *Mira* increased the rape of married women and girls as male members of the household migrated further and for longer periods of time to find work during a drought [490]. Another example from Somalia involves increases in physical violence against boys. Harmful gender norms dictate that boys are expected to generate income for the family. These economic opportunities were constricted during a drought, but if boys failed to support their families, caregivers considered physical violence as merited [492]. These acts of violence occurred after natural disasters, but normative beliefs and attitudes about physical violence often preceded the disaster event, as underscored in focus groups of men and women in Bangladesh following the 2017 floods [485].

Economic stress

The economic shock of natural disasters especially affects households living in poverty [474, 479, 481]. One proposed reason is that men, frustrated by economic loss and hardship, misdirect their anger at sexual partners and children. Men identified insufficient cash assistance after the 2015 Nepal earthquake and economic loss from not harvesting crops before floods in Laos as reasons for why they were physically violent [479, 481]. After flooding in Bangladesh, men who received aid or took out personal loans were significantly more likely to be physically or emotionally violent with their children than those who could rely on personal savings [474]. Financial instability, loss of income generating activities, and economic reliance on others seemed to elicit a similar violent reaction among men. The deeper structural drivers relate to gender norms that dictate that men are supposed to be economic providers and are entitled to act out their emotions on women and children. However, the trigger for the behavior was inextricably linked to economic stress and loss caused by natural disasters.

Women were likewise affected by economic stress. In Sri Lanka after the 2004 Indian Ocean Tsunami, decreases in economic status predicted violence from both mothers and fathers [100]. Mothers in Bangladesh were the member of the household that was most often physically violent against children, and those who did not generate an income outside of their households were over three times more likely to abuse their children emotionally or physically [474]. An interview with a father from the study describes why parents were physically abusive after economic loss, "My child asked me in the morning to bring back cookies when I went outside to search for work. It was happening sometimes when we could only afford to eat once a day, so how could I buy cookies? I couldn't control myself and I slapped the child" (Biswas et al. [474], p. 6). Children could not understand the financial strain on their households, and in demanding superfluous goods, it triggered parents to lash out in frustration and guilt. In addition, children were occasionally physically violent against each other due to economic stress. After Typhoon Bopha in the Philippines, a minority of older children were physically abusive against their younger siblings as a result of competition for limited food and the stress of confined living quarters [478]. Girls, in particular, face physical and sexual violence risk outside of their homes. Economic hardship pushes women and girls into precarious employment where work relationships are often exploitative. Two reports specifically mentioned that employers took advantage of the increased vulnerability and power imbalances to abuse their underage female employees physically and sexually [479, 493].

Negative coping with stress

The literature documents two ways by which negative coping after natural disasters leads to violence against children. First, a proportion of men respond to natural disasters by abusing substances and gambling which exacerbates sexual and physical violence [311,

481, 487]. Evidence from a study in Sri Lanka post-tsunami indicated that fathers' alcohol use was a significant factor associated with committing physical, emotional, or sexual abuse against their children [100]. Similarly, after the 2015 earthquake in Nepal, men negatively coped with stress by purchasing and consuming greater amounts of alcohol despite a three-fold increase in price. Alcohol abuse emboldened men to commit acts of sexual violence against girls in the community [481]. Violence against women by their partners may have further ripple effects on children. For instance, women in Bangladesh who experienced physical, emotional, or sexual violence from their husbands were three times more likely to abuse their children than those who were not [474].

Second, caregivers reported that they had less patience for children during a drought in Ethiopia and after flooding in Bangladesh and as a result, would more frequently and disproportionately chastise their children when asked questions [474, 490]. The phenomenon is poignantly captured in the words of a respondent, "I can't stop my emotions during a devasting situation. My 6 years old child always wants to know about this and about that and it disturbs me. So I say something bad to my child…" (Biswas et al. [474], p. 6). Caregivers' capacity to regulate their anger was eroded by the stress of the disaster, and they misplaced their anger on their children. The inability of adults to regulate their anger also affects children outside of their households. In Papua New Guinea, hungry children who stole vegetables from neighboring plots were repeatedly beaten [486].

An extreme stress reaction to natural disasters can manifest as post-traumatic stress disorder (PTSD) for a minority of the population [497, 498]. The literature identified in this review, however, yielded inconclusive evidence on the pathway between natural disaster exposure, PTSD, and violence. Scott et al. [152] found that the relationship

between exposure to Hurricane Katrina in the United States and emotional bullying was completely mediated by PTSD, using structural equation modeling. The finding contrasted with hierarchical modeling which revealed that PTSD did not predict emotional or physical bullying after Hurricane Katrina [475].

Insecure shelter and living conditions

The safety of shelter and living conditions directly relates to a risk of sexual violence against children after natural disasters [499]. Respondents mentioned several elements of inadequate shelter construction and logistical management that increased risk, including: the ease of entry when flimsy tarp materials were used for temporary housing or the inability to lock housing structures; a lack of privacy due to the design or incomplete construction of shelters which allowed men to see girls while changing clothing; and most commonly, the overcrowding of unknown families into the same living space [311, 476, 479, 482, 487–489]. Rashid and Michaud's [242] study of the effects of flooding on adolescent girls in Bangladesh described shelter risks particular to floods. Adolescent girls were forced to sleep on rooftops due to the submersion of the lower levels of their homes. Sleeping outside produced vulnerability to sexual violence from strangers at night. Girls, furthermore, were increasingly exposed to unknown men while conducting their daily activities outside of the household, such as bathing and using latrines. As was the case with housing, the structure of the bathing and toilet facilities may increase the risk of sexual violence. The spaces and structures had a general inadequacy of lighting and were not gender segregated or securely locked [242, 476, 479, 481]. One report nuances the discussion by stating that although structural insecurity existed in communities prior to natural disasters, the events exacerbated safety risk by limiting the mobility of women and girls [485].

Discussion

We identified multiple pathways between natural disasters and violence against children. Each pathway presents a meaningful juncture to intervene in preventing violence. It is promising that many interventions already exist that can be implemented, and the expertise and operational structure do not need to be built anew. Humanitarian agencies would benefit from linking programmatic activities to pathway structures and ensuring robust coordination across agencies to address all possible paths to violence. As an example, cash transfers for families via male caregivers may alleviate economic stress but may also increase violence against children without changing gender norms that stigmatize men for not being able to provide for their families economically. Another concurrent pathway may lead to violence by way of negative coping with stress. Interventions to prevent violence against children, therefore, need to be multi-pronged and change community norms, provide psychosocial support, and reduce problematic substance use to be effective. Alternative provision of cash transfers to female caregivers would still likely lead to violence against children without intervening on normative gender roles with their male partners and providing psychosocial support and parenting interventions for women. In both instances, identification of the underlying pathways to violence against children aids in making decisions about programmatic structure more intentional and targeted.

Economic stress and negative coping with stress were identified as two important pathways to violence against children in this review. It is unclear if investment should be equal across all pathways, however, and further research should compare the relative importance of these pathways across natural disaster contexts. It is likely that many pathways are still unknown and should be identified to improve the effectiveness of programmatic design. Furthermore, this review indicated that pathways between natural

disasters and violence against children are indirect. An analysis of the effect of natural disasters on violence may mask the underlying relationship without taking mediating factors into account [453, 500]. Future evidence production would benefit from measuring co-occurring factors and accounting for the timing of each element on the pathway between a disaster event and violence against children.

Nuanced information on pathways is key in understanding how natural disasters lead to violence against children. The current evidence base needs greater documentation of the differences in violence occurrence and forms by setting, natural disasters type, and case when concurrent man-made disasters exist [453]. These differences likely have major implications for violence outcomes. In particular, pathways to violence may differ between developed and developing countries. A 20-year study of mental health after natural disasters found that people in developing countries faired far worse than those in developed countries. The authors' suggested that individuals have negative mental health outcomes when they knew that they could not access social services [256]. The implication is that individuals living in developing countries are potentially at greater risk of committing violence against children after natural disasters, given poor mental health indicators, but also, because social safety nets and systems of protection are often not robust [501]. Violence, moreover, may be moderated by past exposure to natural disaster and the ability of communities to develop local positive coping strategies [66]. Both of which should be understood more fully.

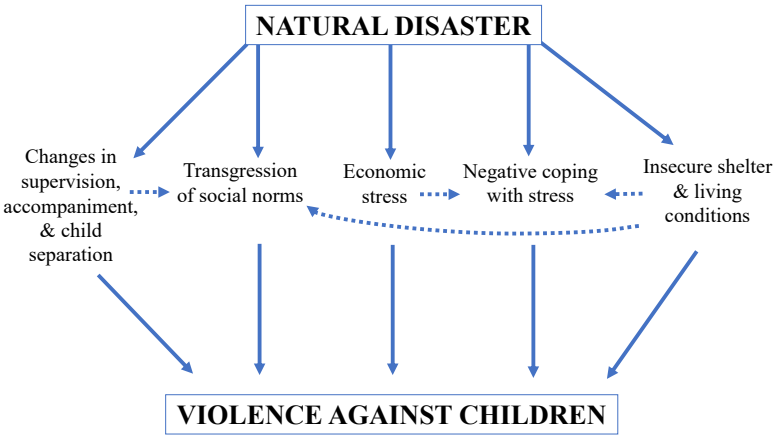
The impact of natural disasters is likely uneven across populations. Gender is an important axis of difference which was not thoroughly explored in the academic or grey literature. Girls and boys experience sexual violence at different levels in stable settings, and this dynamic may be reflected in natural disasters [134]. Past research has found that

people with lower education and minority populations receive less social support in disaster recovery which impacts the ability to cope with an overwhelming situation [502]. Although not a direct measurement, a recent longitudinal study from the United States confirmed that particularly African Americans and Hispanics, individuals with lower levels of education, and those who did not own homes were less likely to recover economically from natural disasters, and in fact, natural disasters entrenched wealth inequalities further [503]. Considering the clustering and intersectionality of poverty, limited educational opportunities, and race and ethnicity, it is probable that natural disasters compound already existent vulnerabilities in specific groups [504, 505].

Our understanding of pathways between natural disasters and violence against children hinges upon the quality of humanitarian evidence gathering and reporting. Much of the information in this review, particularly among the qualitative studies and grey literature, did not present information in a standardized or comprehensive manner which hinders cross comparison and meaningful interpretation. Greater documentation of methods is needed to enable the reader to understand how the data was collected and assess the accuracy of the author's description of pathways. In both qualitative and quantitative studies, the study population should correspond with the research question. The literature base would benefit from interrogating which segment of the overall population of children is represented in each study and its appropriateness; how these choices lead to identification of different pathways to violence; and what biases may exist in reporting information, given the positionality and identity of data collectors in relation to the affected population and the authors' approach in synthesizing information.

Despite the limitations of the existing literature, it is possible to draw a tentative mapping of the likely pathways to violence and possible points of intervention that humanitarian

agencies should consider when designing their programming. The mapping outlined below in Figure 6 presents a starting point in identifying viable points for intervention and creating programmatic structures to prevent violence against children.



Changes in supervision, accompaniment, & child separation	Transgression of social norms	Economic stress	Negative coping with stress	Insecure shelter & living conditions
Community sensitization & risk reduction training (i.e. importance of mixed-gender water & firewood collection)	Menstrual hygiene management kit distribution for violence prevention	Cash transfer & livelihoods programming	Psychosocial support	Shelter engagement on policies for the number & composition of temporary housing units
Risk mapping & adaptation of security planning	Shelter & WASH engagement on gender-segregated sleeping & bathing in temporary housing	Gender-sensitive, psychosocial support to adult male caregivers	Substance abuse counselling	Shelter & WASH engagement on gender-segregated sleeping & bathing in temporary housing
Local income generation programming, tailored to boys & girls	Training of men & boys to prevent sexual violence	Trauma-informed parenting interventions	Integrated prevention programming for intimate partner violence & violence against children	Shelter engagement in secure construction & locking of temporary housing
Incorporation of family & community safety nets into programming	Age- & gender-sensitive income generation programming	Policy & response strengthening for sexual violence in work settings	School-based bullying policy & education	Shelter & WASH engagement on lighting in public spaces & latrines

Figure 6. Pathways to violence against children and potential interventions by pathway type

WASH refers to the Water, Sanitation, and Hygiene sector and programming of a humanitarian response.

Strengths and limitations

We presented a detailed examination of academic and grey literature on the pathways between natural disasters and violence against children. We extensively reviewed grey literature which is often neglected in systematic reviews but is the main body of evidence in the humanitarian field. We included all forms of natural disasters globally, particularly in low- and middle-income countries. Our review, thus, contributes to a better understanding of the research gaps and programmatic opportunities for protecting children from violence in the wake of natural disasters. The review was limited by inconsistent posting of grey literature in online repositories. We examined the prominent grey literature sites for child protection in humanitarian settings, supplementing our search with targeted outreach to key international bodies that lead response efforts. However, we likely excluded sources that were not posted on online clearing houses or were not available in electronic form. Grey literature reports are frequently not shared publicly and so, would not have been identified. As an English language review, we may have missed a subgroup of articles and reports written in non-English languages.

Implications for improving future practice

Humanitarian programs are often designed to address isolated factors on the pathway to violence against children. Our findings illustrate the need to design programming that responds to multiple pathways. Protection interventions that address a single pathway to violence are likely to prove ineffective, because other routes to violence against children continue to exist. A comprehensive mapping of all potential pathways to violence against children after natural disasters would allow for individual agencies to better tailor their programmatic design to key upstream drivers of violence and for coordination bodies to identify any gaps in response efforts. Isolated academic and grey literature sources importantly identified cultural and location-specific coping strategies that were

protective. Families and communities may possess indigenous knowledge that reduces the negative impact of natural disasters and aids in protecting children from violence [480, 484]. As a result, natural disasters may offer opportunities to support and bolster local response efforts. The approach has implications in terms of effectiveness (i.e. building upon existent prevention strategies is easier than promoting strategies seen as externally enforced or outside of societal norms), financing, and paradigm shifts to localize humanitarian response in line with global commitments, such as the Grand Bargain for humanitarian financing [506]. This review likewise highlights our need for greater documentation, given the paucity of sources, and better-quality information for future investigation and intervention.

Conclusion

Humanitarian agencies need to better understand the pathways between natural disasters and violence against children. The pathways identified in this systematic review highlight specific elements of the post-disaster environment that can be leveraged or targeted to create effective interventions. Comprehensive mapping of pathways ensures effective coverage of programming to counter all possible paths to violence. By improving the systematic collection of information to a high standard, we can build more appropriate and targeted interventions to prevent and respond to violence against children.

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CHAPTER 7. RESEARCH PAPER 3 - EFFECT OF INTERNAL DISPLACEMENT FROM THE 2010 HAITIAN EARTHQUAKE ON VIOLENCE

The seemingly contradictory findings of Chapters 5 and 6 spurred me to conduct an original empirical analysis of violence against children after a natural disaster. In this chapter, I analyze the effect of internal displacement from the 2010 Haitian earthquake on long-term violence against children (Objective 1). I apply a matching-based design to test how this aspect of exposure affected violence against children. I secondarily outline a methodological framework for measuring violence after rapid-onset natural disasters in low-resource settings (Objective 3). Given the pitfalls of the studies identified in the prior chapters, I sought to develop a high-quality design that would suit this type of research question, particularly in settings where resources and access to information are constrained.

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London School of Hygiene & Tropical Medicine
Keppel Street, London WC1E 7HT

T: +44 (0)20 7299 4646
F: +44 (0)20 7299 4656
www.lshtm.ac.uk

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SECTION E

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

Ilan Cerna-Turoff[1*]; Jeremy C. Kane[2]; Karen Devries[1]; James Mercy[3]; Greta Massetti[3]; Mike Baiocchi[4]

Affiliation of authors:

[1] Global Health and Development - London School of Hygiene and Tropical Medicine, London, United Kingdom

[2] Mental Health - Bloomberg School of Public Health, Johns Hopkins University, Baltimore, Maryland, United States

[3] National Center for Injury Prevention and Control - Centers for Disease Control and Prevention, Atlanta, Georgia, United States

[4] Medicine - Stanford Prevention Research Center, Stanford University, Palo Alto, California, United States

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 biases. 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

Introduction

On January 12, 2010 Haiti experienced a 7.0 magnitude earthquake near the capital city of Port-au-Prince [508]. Port-au-Prince lost an estimated 23% of its population from internal displacement to camps, informal settlements, and other regions of the country [509]. 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 [95, 510]. 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 [322, 359]. 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 [102, 321]. A study that isolated the 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 [297]. 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 [242] 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 [311, 476].

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 [184]. Natural disasters and

internal displacement increase economic hardship, especially for low-income families [511]. New financial strains may cause caregivers to migrate 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 [512]. Children further may be forced to work in order 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 due to the increase in distance after displacement to separate regions [420].

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 [255, 474]. Negative coping behaviors, such as hazardous alcohol usage, often increase after natural disasters which presents 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, $p < 0.01$) [100]. Economic hardship further leads to caregiver stress, resulting in harsh acts of physical or emotional violence [474].

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, $p < 0.001$) [79]. Specific to Haiti,

the prevalence estimates for post-traumatic 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 ($p < 0.01$) [513].

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 [141, 514]. 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 [515]. 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 [96]. 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 [112]. Children are overrepresented in humanitarian emergencies, representing 48 million of those who required assistance in 2017 [516]. Most evidence that documents the relationship between widescale catastrophic events and violence against children, however, comes from man-made disasters, and less is known about possible differences in violence patterns after exposure and displacement from natural disasters [458, 517–519].

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 [98, 99]. Studies commonly rely on the chance existence of prior data collection with the affected population and less commonly, on a cross-sectional

survey afterwards [102, 520]. 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 [104]. 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 [130, 521, 522]. 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 [523]. 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 [523]. The resulting estimates are less influenced by other factors that would typically confound observational studies [252].

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.

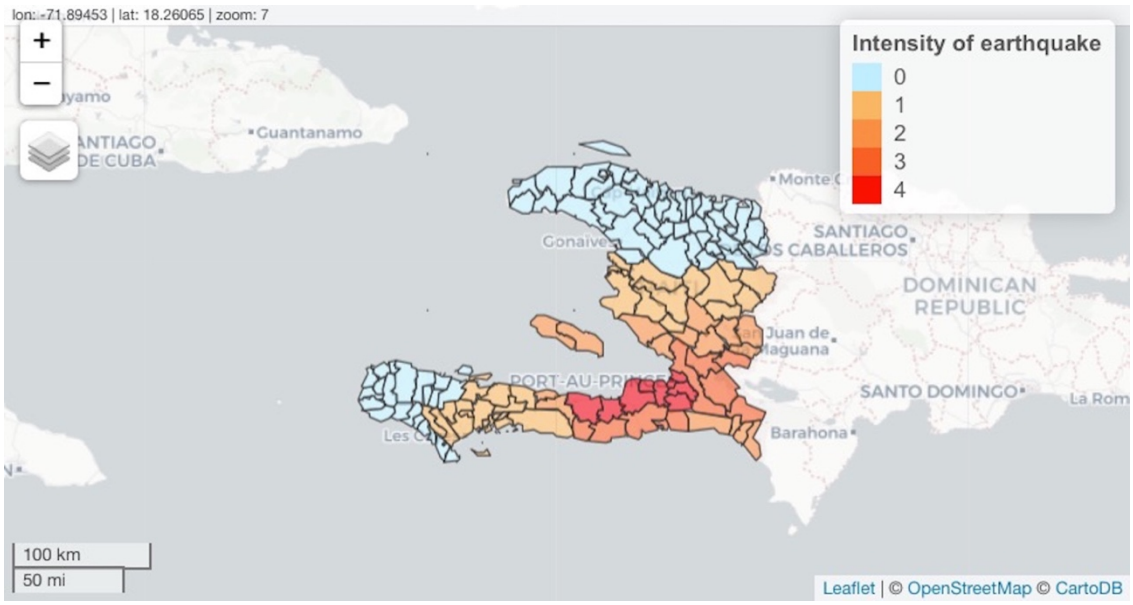

Figure 7. Mapping of shake intensity by communes

Data source is the United States Geological Survey and map produced in the `Mapview` package [524, 525].

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, 1457 girls and 1459 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 [427].

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 to 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) [427].

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 all possible covariates in the survey that had data structures appropriate for determining that they had occurred prior to the earthquake and that could theoretically have biased the association between earthquake exposure and violence against children. We 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 bias 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. 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 [103].

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 3) [526]. 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 [134], were highlighted as most important for girls and boys in Haiti during a qualitative pre-study of the VACS [436], 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 [527].

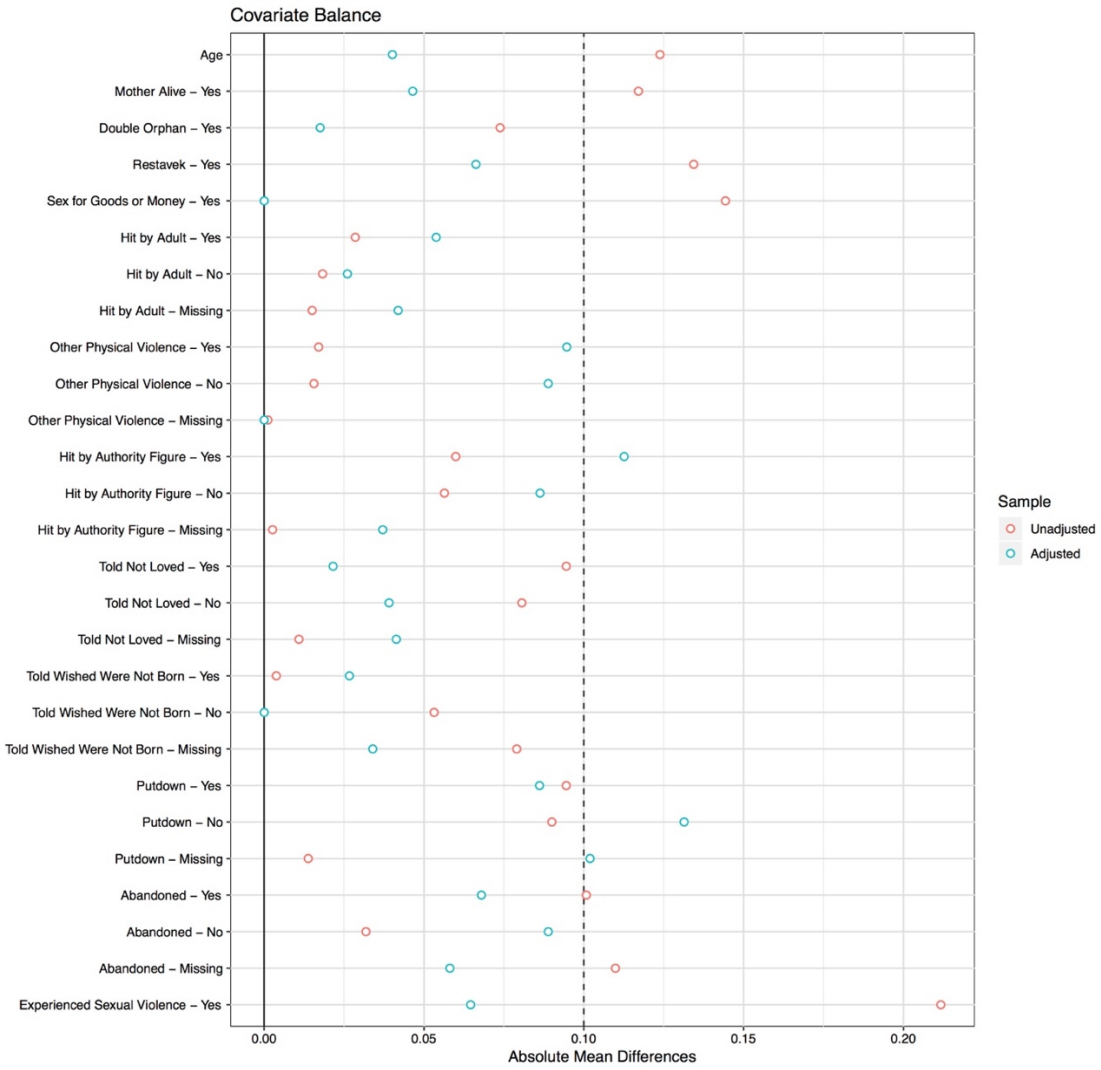

Figure 8. Love plot of pre-earthquake covariate balance before and after matching for girls

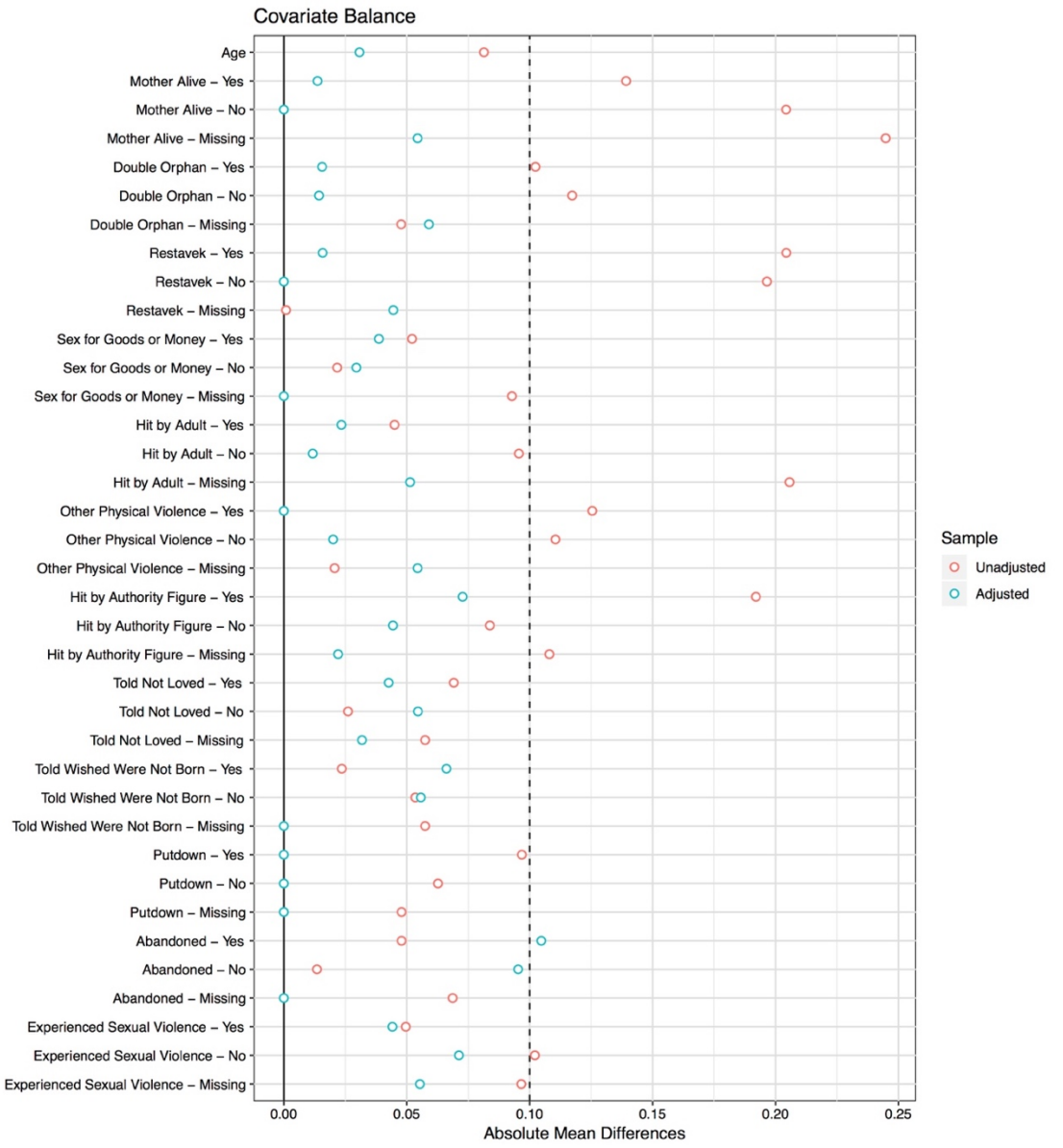

Figure 9. Love plot of pre-earthquake covariate balance before and after matching for boys

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 4-5) [528]. We additionally ran power calculations to determine the quality of the trimming and matching and identify if the sample size prior to statistical analyses was sufficient to

detect changes in violence after the earthquake, based upon pre-earthquake estimates of violence in Haiti (see Supplementary Files 6-8).

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 covariates to alter our observed results [103]. The data were cleaned in Stata 15 and matched and analyzed in R v.3.3.3 [452, 529].

Results

Description of the study population

The original sample included a total of 157 girls and 174 boys displaced either to camps or communities. 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%) [530]. 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.

Table 8. 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%

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 $h = 0.20$) [531, 532].

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. The confidence intervals had wide variability and crossed 1.0 in all instances, indicating that no discernable difference existed between the exposed and comparison group of girls. Multivariate analysis combining violence outcomes followed a similar pattern, with no appreciable difference between 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 covariates (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 and had confidence intervals that crossed 1.0. 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 covariates (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 9. 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 estimates for the affected population of children that remained in Haiti after the earthquake.

We attempted to make the minimum number of assumptions possible in estimating the population level ATT. Our study assumed a Strongly Ignorable Treatment Assignment (SITA) and used the Stable Unit Treatment Value Assumption (SUTVA). A SITA implies that all important covariates are measured and that the matched pairs are exchangeable, except for their exposure, and the SUTVA assumes that spillover effects do not exist during individual displacement and that one version of an exposure exists [432, 533]. We used matching to increase exchangeability between exposed and comparison groups which likely fulfilled a SITA assumption. Sensitivity analysis further indicated that the results were 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. The SUTVA, on the other hand, is a stronger assumption. It is conceivable that the internal displacement of children

to non-earthquake regions increased the risk of violence against non-displaced girls and boys which 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 methods that to our knowledge have not been implemented with survey data in humanitarian emergencies. We felt comfortable making this assumption, given our current lack of knowledge on how patterns of internal displacement lead to violence in receiving communities. Nevertheless, the SUTVA may not always hold.

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 [453]. Specific analyses that isolated the 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, $p < 0.05$) [308]. Among adult women, residing in an IDP camp increased the probability of physical and sexual violence but not displacement from the Haitian earthquake [297].

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 [66, 69]. Kolbe [102] 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 [297] 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 [534]. 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 [535].

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 [436]. Their analysis did not adjust for pre-earthquake violence, measure the effect of displacement on violence, or compare the estimates with the population of IDPs who no longer lived in camps. A related limitation is that we did not have a measure of earthquake intensity that could have been used to partition exposure into any unexplained deviation from randomness. While an instrumental variable analysis would have offered an additional mechanism to reduce possible biases in exposure, displacement as a clear binary question is less sensitive to unmeasured biases than incremental changes in earthquake intensity [440]. This point may be salient in terms of a related national study on intimate partner violence against

adult women in Haiti which used three gradations of earthquake intensity to determine exposure [297].

We could not include certain covariates in the matching metric that are typically associated with violence in other settings, namely pre-earthquake place of residence and socio-economic status [536]. Geographic residence in where the children lived before the earthquake may have biased this study's conclusions towards the null. Available data indicates that Port-au-Prince had a lower corporal punishment prevalence than rural or other urban areas of Haiti before the earthquake [531]. In contrast, poverty would have biased away from the null in this sample, given that poverty is a risk factor for violence [521]. The temporary and powerful mass disruption of the Haitian earthquake on the population-level likely helped to reduce both of their influences in this analysis [537].

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 [432]. 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 [418, 538]. 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 covariates 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 [427]. 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.

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 representative sampling structure of the VACS and minor extent of trimming among displaced individuals allowed us to target a population level treatment effect on the treated since the parameter in the sample serves as a good proxy for all children that remained in Haiti after the earthquake. The sample size used for our analysis after trimming and matching 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 [539]. 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.

Implications and conclusions

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 [540]. 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 [541]. 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 [297]. 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 [100, 256, 458]. 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 [542].

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 [98, 99]. 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 [543]. Rapid-onset natural disasters are specifically suited for this method, because they act as population randomizers, and unlike man-made disasters, may exhibit less strong spatial patterns [544]. 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 bias inherent in observational studies [545].

Acknowledgements

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conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.

CHAPTER 8. RESEARCH PAPER 4 – PERFORMANCE OF DESIGN APPROACHES IN REDUCING BIASES AND INCREASING ACCURACY

This chapter builds upon the methodological framework presented in Chapter 7. The outlined methodological framework highlighted the importance of collecting and pre-processing data to create pre-exposure covariates for matching in order to correct measurement error. As such, it ultimately related to obtaining higher quality column variables for a data frame. I now turn to the issue of selecting individuals that sort themselves into one's study in a manner that introduces bias. This chapter, therefore, focuses on the quality of individual observations, or the rows of a data frame.

This chapter responds to the findings from the gamma sensitivity analyses in Chapter 7. Most results in the previous chapter could withstand a high level of unmeasured bias, except for sexual violence against girls and physical violence by authority figures against boys. Sensitivity analyses do not directly indicate that unmeasured biases exist or provide tools to address them [440]. In this methodological chapter, I introduce a blended design approach—*full matching incorporating an instrumental variable (IV)* or *Full-IV Matching*—that can mitigate biases from observed and unobserved covariates and increase the accuracy of estimates to measure the effect of internal displacement from natural disasters on violence against children within population-based surveys (Objective 4). This chapter, therefore, provides a method that seeks to address directly the potential threats from unmeasured biases identified in Chapter 7. Sexual violence against girls after earthquake-caused displacement to a camp setting is employed as the motivating example to illustrate the applicability of Full-IV Matching to research questions that are related to those of this thesis.

I will submit this manuscript to the American Journal of Epidemiology. The journal is open access under a creative commons license (CC BY-NC 4.0 – https://creativecommons.org/licenses/by-nc/4.0/). The supplementary materials referenced in the manuscript are provided at the end of the thesis as Appendix E.

LONDON SCHOOL of HYGIENE &TROPICAL MEDICINE

London School of Hygiene & Tropical Medicine
Keppel Street, London WC1E 7HT

T: +44 (0)20 7299 4646
F: +44 (0)20 7299 4656
www.lshtm.ac.uk

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Student ID Number	1514051	**Title**	Mr
First Name(s)	Ilan Salvador		
Surname/Family Name	Cerna-Turoff		
Thesis Title	Understanding and measuring the complex relationship between natural disasters and violence against children		
Primary Supervisor	Dr Susannah Mayhew		

If the Research Paper has previously been published please complete Section B, if not please move to Section C.

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Where was the work published?			
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Where is the work intended to be published?	American Journal of Epidemiology
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Stage of publication	**Not yet submitted**

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	I designed the study, analyzed the data, and wrote the manuscript.

SECTION E

Student Signature	[redacted]
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Pre-processing data to reduce biases: full matching incorporating an instrumental variable in population-based surveys

Ilan Cerna-Turoff[1*]; Katherine Maurer[2]; Michael Baiocchi[3]

Affiliation of authors:

[1] Global Health and Development, London School of Hygiene and Tropical Medicine, London, United Kingdom

[2] Social Work/Centre for Research on Children and Families, McGill University, Montreal, Québec, Canada

[3] Medicine/Stanford Prevention Research Center, Stanford University, Palo Alto, California, United States

Abstract

Background

Epidemiologists are often interested in research questions that do not lend themselves to experimental designs and instead rely upon population-based surveys to collect observational data. The biases inherent in these data threaten the quality of inference. Biases often result from pre-exposure differences between exposed and unexposed individuals that lead to confounded estimates. Several statistical techniques, such as regression, propensity scores, and matching, can mitigate biases caused by measured covariates. These methods, however, do not account for unobserved sources of bias. In this paper, we introduce a novel design approach, known as *full matching incorporating an instrumental variable (IV)* or *Full-IV Matching*, to illustrate its utility in reducing biases from observed and unobserved covariates to increase the accuracy of inference within population-based surveys.

Methods

We conducted a Monte Carlo simulation generated from a nationally representative household survey in Haiti after the 2010 earthquake. Our motivating example is tailored to a central epidemiological question in humanitarian emergencies—the effect of displacement to a camp setting on sexual violence against girls. We simulated values for several covariates which are considered "observed" and one variable—*social capital*—which is unobserved. We subsequently compare biases and accuracy of estimates after full matching and Full-IV Matching. Balance tables are utilized to understand the effect on biases, and generalized linear mixed models aid in assessing the accuracy of each design.

Results

Relative to an unadjusted comparison, full matching improved the balance between exposed and comparison groups across key covariates but did not balance the unobserved covariate of *social capital*. The full matching analysis overstated the connection between sexual violence and displacement to the camp (β = 0.98). Full-IV Matching reduced imbalances across observed covariates and importantly, the unobserved covariate. The resulting estimate similarly indicated that displacement to the camp was correlated with sexual violence (β = 0.49) but was closer to the true causal estimand in the underlying simulated data (0.4).

Conclusion

Full-IV Matching is a novel design approach that can mitigate biases from both observed and unobserved covariates under certain conditions. This approach is promising for increasing the accuracy of inference within population-based health surveys, particularly when epidemiologists believe that unmeasured sources of bias exist.

Keywords

Matching; instrumental variable; unobserved bias; survey; observational data

Introduction

A wide array of social research questions do not lend themselves to experimental design. As an alternative, epidemiologists commonly rely on observational data in the form of population-based surveys [546]. Observational data has inherent biases that threaten the quality of inference. Pre-exposure differences between exposed and unexposed individuals may lead to confounding, distorting effect estimation. Epidemiologists endeavor to counter this threat by designing surveys to measure background covariates

and applying regression, propensity scores, or other matching techniques to reduce biases [432, 444, 547]. Other sources of bias may still exist, even after addressing the observed covariates. A central concern is that individuals may be more likely to be exposed because of unmeasured characteristics that influence individual choices and behavior [548]. These deviations reduce the randomness of exposure probability and increase likely biases in inference [548, 549].

Instrumental variables, here forward abbreviated as "IVs", were developed with the idea of reducing unobserved sources of bias [550]. The inclusion of an IV in analysis is particularly useful for population-based surveys, given the likely biases. Epidemiologists may be investigating a research question that was not implicitly part of the survey design, and all relevant covariates may not be measured. IVs can be used to produce valid effect estimates when covariates are unmeasured or even unknown [551].

Traditionally, IVs were designed using regression analyses [550]. Much less attention has been paid to the application of IVs within matching-based designs [552, 553]. In this paper, we introduce *full matching incorporating an IV* or *Full-IV Matching* and illustrate its utility in reducing measured and unmeasured biases to increase the accuracy of effect estimation. An epidemiological study on how displacement to a camp affects sexual violence against girls serves as the motivating example.

Designing data in matching-based approaches

Rubin [554] made the provocative claim that design trumps analysis in observational studies. By this, he meant that study components before the final application of an analysis method are most important in causal inference. Rubin proceeded to outline an argument that after data is collected, propensity scores or matching methods must be

applied to observational data to approximate a randomized experiment and produce unbiased causal estimates [554]. In essence, this approach evokes the idea that not all data collected in the real world is useful in its raw form and must be pre-processed to be similar to a scientific experiment [555]. Often, a segment of one's observations will be discernably biased, as individuals may sort into a study in ways that are outside of an epidemiologist's control, even after random sampling [556]. Rubin and others emphasize that the loss of some observations from a population-based survey may be justified to increase internal validity [103, 433, 554]. This paper describes approaches to pre-processing data which illustrate the pure contribution of design in increasing the accuracy of inference.

Instrumental variable definition and designs

IVs are factors that are pivotal in driving the type of exposure received [553]. For example, past studies have used distance to specialty perinatal care providers for mortality of premature infants [557]; day of the week for hospital admission [558]; and the order of one's military draft lottery number on later veteran mortality [550]. By definition, IVs influence the exposure probability but are not related to unmeasured covariates and do not exert an influence on the outcome besides via their influence on the exposure [550].

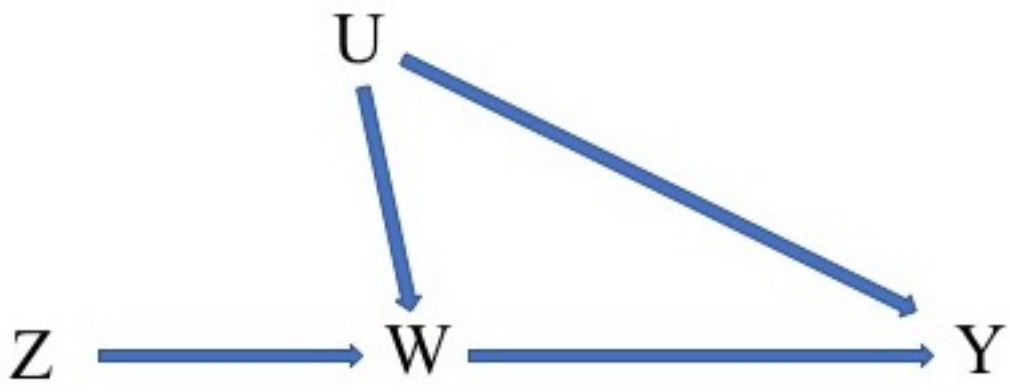

Figure 10. Directed acyclic graph for the causal structure of an instrumental variable analysis

Z = instrument; *W* = exposure; *Y* = outcome; *U* = unmeasured covariate. Directed acyclic graphs (DAGs) are causal diagrams that provide unidirectional graphical representations to illustrate the ordering and relationship between variables [559].

Analyses that use IVs partition the direct effect of the exposure on an outcome from any residual that is due to the unobserved covariate [560]. Exposure status, therefore, is closer to random, and estimates are less influenced by unobserved covariates that may influence exposure probability [550]. Several excellent overviews exist for IV methods, of which we would point the reader to Greenland [552], Glymour [551], and Baiocchi et al. [553].

Epidemiologists infrequently have utilized IVs when analyzing observational data from population-based surveys [552]. When applied, the IV is often included directly within the inference stage of the analysis using regression-based modeling [553]. A separation of data design and inference offers several advantages. First, the matching metrics are non-parametric and rely upon fewer assumptions (e.g. linearity) than regression-based IVs [449, 551, 560–562]. Second, matching-based IV designs do not risk model misspecification which reduces potential error [563]. Third, these designs are well-suited to binary data structures. Regression-based IVs were developed for continuous outcomes,

but binary data structures are common in population-based surveys [561, 564, 565]. A two-stage least squares (2SLS) with a logistic or probit model in the second stage of the regression has been proposed as a solution to binary outcomes within a regression-based IV analysis [560, 566]. Biases, however, tend to increase when events are highly common or rare, and causal odds ratios are likely biased even in large samples [560, 562]. Simulation studies have illustrated that matching-based IV designs are better suited for binary data when conducting different types of matches, including: near/far matching for 1:1 pairs [553], fixed control matching [567], or full matching [451]. Residual inclusion models are a recent extension within a regression framework that produce less biased estimates than 2SLS, and matching-based IVs offer a suitable alternative [568]. Last, matching-based IV designs increase transparency in the scientific community's assessment of the quality of the IV in that epidemiologists can directly assess the likely bias reduction via balance statistics [449, 451, 557].

Full-IV Matching outlined in this paper has two main advantages to past IV approaches. First, it provides an applied solution of how to combine full matching with an IV. Full matching creates varying combinations of sets of individuals so that weighted composite profiles are matched to each other. The result produces lower standard errors and more precise estimates as compared to pair matching since less data needs to be discarded [444, 448]. Full matching requires different matching algorithms and inference methods than are used for pair matching. We provide the reader with usable code for how to conduct this form of design and produce simple summary statistics within existing statistical software but stop short of creating tailored statistics for inference to emphasize the benefits of solely design in reducing biases and to provide a constant comparison between full matching and Full-IV Matching. Second, Full-IV Matching permits the epidemiologist to modulate the strength of a continuous IV. This property is one of the

design's most important properties. As such, if concern exists that a covariate was not measured during data collection and that it would highly influence estimates, Full-IV Matching allows the epidemiologist to decide how much "weight" should be given to the unobserved covariate. Although increasing the strength of the IV has the trade-off of reducing the number of observations available for inference, one has increased control over specifying the level of unmeasured bias, and the full matching component of the algorithm initially uses a greater amount of data.

Assumptions

Both matching and IV designs have assumptions, such as the Stable Unit Treatment Value Assumption (SUTVA). SUTVA assumes that the exposure for one individual unit does not have a spillover effect on others and that multiple versions of the exposure do not exist [533, 553]. IVs additionally have their own set of assumptions, regardless of which IV method one selects [550]. These assumptions include: (i) the instrument has a positive causal effect on the outcome; (ii) the instrument only affects the outcome by way of the exposure, called the *exclusion restriction*; (iii) the outcome and the instrument do not share a common cause, called the *independence assumption*; and (iv) no individuals that defy their exposure exist, known as the *monotonicity assumption* [553, 569]. In this example, we created a constant treatment effect for the data generation function to illustrate the benefit of our methodological approach. As a result, the typical target parameter of an IV analysis—the Complier Average Causal Effect (CACE)—would be identical to other target parameters, for example, the Average Treatment Effect (ATE) and the Average Treatment effect on the Treated (ATT).

Methods

We conducted a Monte Carlo simulation to create a synthetic dataset similar in structure to a nationally representative household survey but with additional variables that were not available in the original dataset [570]. Full-IV Matching is compared to full matching to illustrate the benefits of the design approach. We hold constant the estimators to isolate how much selection bias could be reduced by changing data design, so unlike traditional simulation studies, the focus is not on estimator behavior and performance. Balance tables make explicit the effect on biases, and generalized linear mixed models (GLMM) are used to assess the accuracy of each design in estimating the true causal estimand in the underlying synthetic dataset. Analyses were conducted in R v.3.3.3 [452].

Motivating example

We apply the motivating example of an epidemiological study of violence after the 2010 Haitian earthquake. Numerous studies reported that mass displacement of millions to internally displaced persons (IDP) camps and surrounding communities led to widespread sexual violence against girls [102, 322]. We previously analyzed the long-term effect of internal displacement from the 2010 Haitian earthquake on violence nationally [507]. In this hypothetical example, a cross-sectional survey was conducted with a random population-based sample of 5000 girls who were displaced either to a camp or to the wider community, with the goal of understanding the effect of displacement to a camp setting on sexual violence.

Data-generating process

We generated a synthetic dataset from values of several variables within the Haitian Violence Against Children Survey (VACS)—a nationally representative household survey [427]. In addition, we created two variables that were not among the original

"observed" covariates derived from the VACS: (i) an unobserved covariate of *social capital* and (ii) an instrumental variable of the *severity of earthquake damage to the girls' home communes*. We simulated five baseline covariates in total (X_1, …, X_5) for each girl that would be present in the underlying population before possible displacement into the camp. Three covariates were generated from a Bernoulli distribution which include: (i) working as a *restavek* (a form of child labor marked by indentureship of poor children to rich families in Haiti), (ii) prior sexual violence, and (iii) the unobserved covariate of *social capital*. We further generated *living with parents*, which utilized a discrete categorical distribution with an assigned number for each category, and a covariate for age based upon a uniform distribution to have equal probability across the observed range of ages in the survey. The establishment of baseline covariates is analogous to recruitment of individuals into a study. We additionally added an interaction term between age and prior sexual violence to recognize the possible compounded risk of future sexual violence from intimate partners among older girls. The inclusion of interaction terms diversifies data structures found in the original survey and acknowledges the intersectional dynamics when one has multiple identities or experiences may lead to non-additive effects. *Severity of earthquake damage to the girls' home communes* was generated from a random normal distribution and served as the IV for this analysis. The exposure of interest (displacement to the camp) and the outcome of sexual violence were also binary and therefore, generated from a Bernoulli distribution[12]. We likewise added an interaction term when generating the outcome, because not living with parents who are perpetrators of past sexual violence may be protective for future violence risk, or past sexual violence may increase risk taking behaviors which are exacerbated when a girl does not live with her parents.

[12] Bernoulli distribution is appropriate for individual binary exposures and aggregates to a random binomial distribution on the population level [637].

Displacement into camp (exposure):

$$Pr(Y = 1) = g(\propto_0 + \propto_2 Z + \propto_1 X_1 + \propto_2 X_2 + \propto_3 X_3 + \propto_4 X_4 + \propto_5 X_5 + \propto_6 X_1 X_2)$$

Sexual violence each girl (outcome):

$$Pr(Y = 1) = f(\beta_0 + \beta_e e + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_2 X_3)$$

Z = severity of earthquake damage

e = exposure of displacement to the camp

X_1= age

X_2= past sexual violence

X_3 = living with parents

X_4 = *restavek* status

X_5 = social capital

g, f = inverse logit functions

In generating these variables, we initialized the alpha and beta coefficients using the actual VACS dataset so that we could create marginals for the exposure and outcome that were relatively similar to the real data. We, then, had to adjust the values of the coefficients to accommodate the addition of the unobserved covariate of *social capital*, instrument of severity of earthquake damage, and interaction terms. The alphas and betas for the exposure and outcome are as follows,

Simulation values for displacement into camp (exposure) on a linear scale:

$$-4.2 + 1(Z) + 0.1(X_1) + 0.34(X_2) + 0.1(X_3) + 0.21(X_4) + 4(X_5) + 0.05(X_1 X_2)$$

Simulation values for sexual violence each girl (outcome) on a linear scale:

$$-9.2 + 0.8(e) + 0.3(X_1) + 1.8(X_2) + 0.2(X_3) + 0.9(X_4) + 3(X_5) + 0.1(X_2 X_3)$$

Full matching

We selected characteristics and experiences of the girls reported as occurring before displacement for use in the matching algorithm. Although numerous matching algorithms exist, we selected Mahalanobis distance as our metric with optimal full matching and used the same matching algorithms in Full-IV Matching for comparability [443, 444].

Full-IV Matching

We designated *severity of the earthquake damage to the girls' home communes* to be the IV. This variable is a plausible IV, as it likely would act as a randomizer that is upstream of displacement and "strongly encourages" a girl to be displaced in the real world [550]. We divided girls who resided in areas with high and low earthquake damage levels to create polar extremes of encouragement for the IV and carved out weak middle values that would be less suitable for use. In this step, the epidemiologist determines the strength of the IV. We designed a strong value (bottom 10^{th} percentile and top 90^{th} percentile) for illustrative purposes. Matching algorithms were created to produce pairs or sets of individuals with similar scores, and therefore, high-to-low values of the IV must be translated before matching to ensure that sets of individuals are far apart on their IV [444]. The process is shown below in Figure 11 A-C.

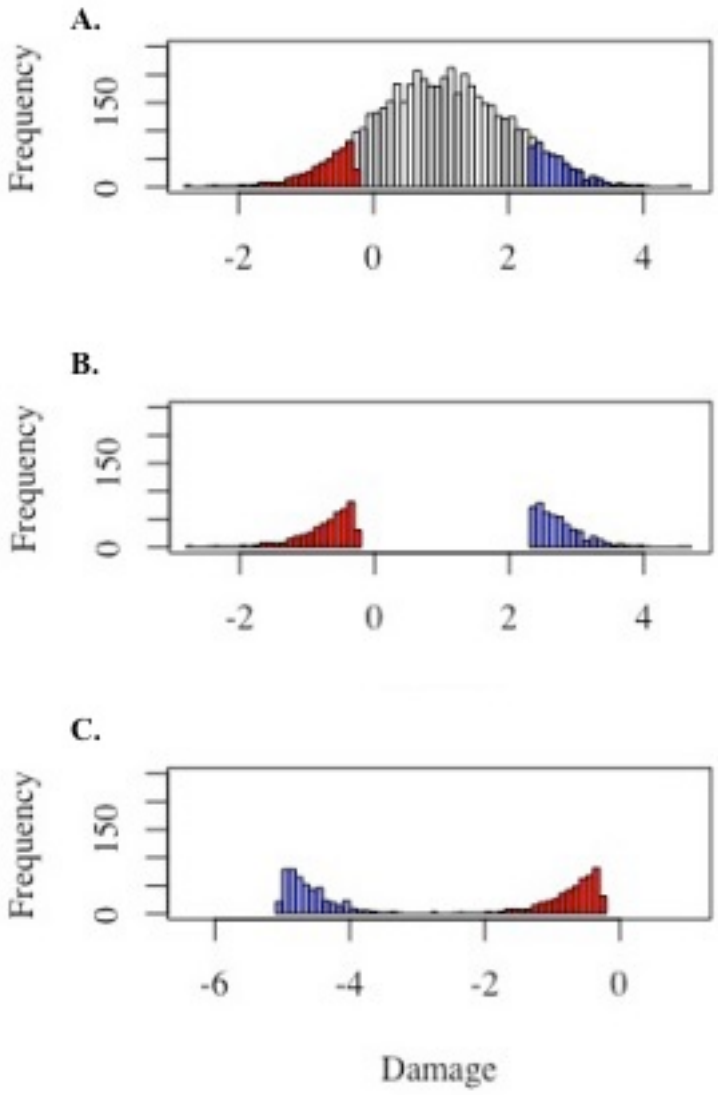

Figure 11. Histograms illustrating the translation of the IV

Figure 11-A illustrates the distribution of IV values for all observations within the dataset. Figure 11-B illustrates the high and low values of the IV after carving out weak encouragement values; the bottom 10th percentile is in red and the top 90th percentile is in blue. Figure 11-C illustrates the translation of IV values necessary for matching with an IV.

We matched on covariate distributions across sets of girls (the algorithm attempts to identify girls that are near in their pre-earthquake covariates) and far values of the IV (the algorithm attempts to separate girls on earthquake damage levels for the girls' home communes) [449]. We utilized Mahalanobis distance as the metric and optimal full

matching, equivalent to the prior full matching design[13]. Current statistical software packages do not have an option for including the IV within optimal full matching algorithms [450, 451]. We wrote a useable code manually which is provided for reference and future use in R (Appendix 1).

Assessment of bias and accuracy

Balance tables are used to assess quantitative differences between exposed and comparison groups in standardized mean differences (SMD) across key covariates. A SMD of less than +/- 0.10 indicates that groups are comparable for each covariate, whereas SMDs that are greater than +/- 0.20 indicate a high level of imbalance [571]. The performance of the matching algorithm is judged on improving the covariate balance between exposed and comparison groups to the greatest extent possible for those covariates that would bias estimates, and covariate balance is more important than model fit in match performance [433]. Each covariate can be assessed for balance before and after matching. Due to the simulated nature of this dataset, one can assess balance statistics for the unobserved covariate of *social capital* which would normally be hidden in the real world. The simulated nature of the data further permits a direct comparison of accuracy between statistical methods, because the underlying truth of how the covariates affect the parameter of interest (sexual violence) is known [441]. In other words, we created the strength of the effect of displacement to a camp in relation to the covariates in this simulation, so we can compare how each approach faired in estimation.

[13] Mahalanobis distance is a sensible metric for comparison between full matching and Full-IV Matching, because propensity scores cannot be used in IV settings. Propensity scores assume strongly ignorable treatment assignment (SITA) and are fit using realized exposure levels. This assumption implies that all information is measured in the observed covariates and that matched pairs or sets are exchangeable, except for their exposure [432]. Propensity scores would enforce biases if used for IV matching designs where unobserved covariates are present [449].

Results

Full matching markedly increased the balance between exposed and comparison groups from pre-match levels across observed covariates (less than +/- 0.10 SMD) (refer to Table 10). In particular, pre-displacement sexual violence was imbalanced between exposed and comparison groups before matching. Past or ongoing experiences of sexual violence would be highly likely to predict future sexual violence and without address, would lead to bias in estimates [572]. In estimation, displacement to the camp was strongly correlated with sexual violence (β = 0.98, 95% CI 0.78-1.17, $p < 0.001$).

Table 10. Quantitative assessment of covariate balance between groups before and after full matching

Characteristic	Overall population	Before match			After match		
	Study population (N = 5000)	Exposed (N = 4202)	Comparison (N = 798)	Δ (SMD)	Exposed (N = 793)	Comparison (N = 793)	Δ (SMD)
Age – yr (mean - SD)	15.01 (1.15)	15.01 (1.15)	15.03 (1.13)	-0.02	15.00 (0.01)	15.00 (0.01)	-0.00
Living with parent – n (%)							
Both parents	2952 (59.0)	2452 (58.4)	500 (62.7)	-0.09	471.84 (59.5)	488.49 (61.6)	-0.04
No father	520 (10.4)	452 (10.8)	68 (8.5)	0.07	79.30 (10.0)	70.58 (8.9)	0.04

No mother	1484	1257	227	0.03	230.76	230.76	0.00
	(29.7)	(29.9)	(28.4)		(29.1)	(29.1)	
Neither parent	44	41	3	0.06	11.26	3.13	0.11
	(0.9)	(0.1)	(0.4)		(1.42)	(0.40)	
Restavek* – n (%)							
Yes	500	424	76	0.02	76.68	77.56	-0.00
	(10.0)	(10.1)	(9.5)		(9.67)	(9.78)	
Experienced prior sexual violence – n (%)							
Yes	1750	1545	205	0.23	268.83	214.11	0.15
	(35.0)	(36.8)	(25.7)		(33.9)	(27.0)	
Interaction term (age x prior sexual violence, mean - SD)	5.25	5.52	3.85	0.23	5.09	4.05	0.15
	(7.19)	(7.27)	(6.59)		(0.10)	(0.10)	

Observations are weighted to calculate the Average Treatment Effect (ATE) for the full matching. Even though this sample has a constant treatment effect (ATE = ATT = CACE), the frequencies for the population demographics in the table change depending on which target parameter is chosen. All

individual observations for the exposed (n = 4202) and comparison (n = 798) groups were used in the matched sets. Weighted frequencies, standard deviations (SD), and standardized mean differences (SMD) are rounded to two decimal places.

Full-IV Matching produced a noteworthy balance in the observed covariates (refer to Table 11). It additionally reduced imbalance in the unobserved covariate of *social capital* which sets it apart from a full matching approach. Sorting of girls into camps or communities is likely to have occurred in ways that were not captured by the observed covariates in this dataset, and the hard-to-measure variable of *social capital* might have protected girls from being displaced into camps if they had wider networks of support [509]. Differences in *social capital*, therefore, would likely lead to bias. Similar to full matching, displacement to the camp is still correlated with sexual violence (β = 0.49, 95% CI 0.23-0.78, $p < 0.01$) but to a lesser degree than the prior study design.

Table 11. Quantitative assessment of covariate balance between groups before and after Full-IV Matching

Characteristic	Covariate type	Full matching			Matching incorporating an IV		
		Exposed (N = 793)	Comparison (N = 793)	Δ (SMD)	High IV (N = 500)	Low IV (N = 500)	Δ (SMD)
Age – yr (mean - SD)	Observed	15.00	15.00	-0.00	15.10	15.00	0.03
		(0.01)	(0.01)		(0.07)	(0.07)	
Living with parent – n (%)	Observed						
Both parents		471.84	488.49	-0.04	277.00	298.00	-0.09
		(59.5)	(61.6)		(55.4)	(59.6)	
No father		79.30	70.58	0.04	52.00	41.00	0.08
		(10.0)	(8.9)		(10.4)	(8.2)	

No mother		230.76	230.76	0.00	116.00	158.00	0.03
		(29.1)	(29.1)		(33.2)	(31.6)	
Neither parent		11.26	3.13	0.11	5.00	3.00	0.04
		(1.42)	(0.40)		(1.0)	(0.6)	
Restavek* – n (%)	Observed						
Yes		76.68	77.56	-0.00	48.00	51.00	-0.02
		(9.67)	(9.78)		(9.6)	(10.2)	
Experienced prior sexual violence – n (%)	Observed						
Yes		268.83	214.11	0.15	180.00	163.00	0.07
		(33.9)	(27.0)		(36.0)	(32.6)	
Interaction term (age x prior sexual violence, mean - SD)	Observed	5.09	4.05	0.15	5.41	4.88	0.07
		(0.10)	(0.10)		(0.07)	(0.07)	
Earthquake damage level	Instrument	1.28 (0.04)	-0.45 (0.04)	2.22	2.75 (0.11)	-0.74 (0.11)	8.78
Social capital	Unobserved	572.55 (72.2)	468.66 (59.1)	0.29	352.00 (70.4)	352.00 (70.4)	0.00

Observations are weighted for full matching and Full-IV Matching. Weighted frequencies, standard deviations (SD), and standardized mean differences (SMD) rounded to two decimal places.

Discussion

Full matching reduced bias considerably by addressing imbalances across observed pre-exposure covariates. The choice to match girls who mirror each other, except for their displacement into or outside of the camp, identified good counterfactuals, increasing exchangeability within matched sets and isolating the effect of displacement to the camp on sexual violence against girls. The separation of pre-earthquake characteristics from exposure further aided in reducing potential biases in effect estimation [432]. While full matching directly balanced observed covariates, *social capital* was still substantially imbalanced at 0.29 SMD, as can be noted in the second balance table. In contrast, Full-IV Matching pulled apart values of the IV from 2.22 to 8.78 SMD. In doing so, it reduced imbalance in the unobserved covariate of *social capital* by approximately 30% from the prior full match. Full-IV Matching balanced all observed and unobserved covariates and as a result, diminished the influence of measured and unmeasured sources of bias on the estimate.

We additionally can compare the quantitative actuality of how each method biased away from the true causal estimand of sexual violence in the camp, since we have access to the data generation function of the synthetic dataset. The true estimand of sexual violence is 0.4. After full matching, the returned estimate was β = 0.98. At the pinnacle, Full-IV Matching most reduced biases at β = 0.49. We illustrated that a matching-based IV design yielded the more accurate estimate in this dataset.

Limitations

Full-IV Matching is not without limitations. In particular, the SUTVA may be difficult to assure in the real world. Receiving communities may change as a result of the influx of displaced children, and multiple variations of exposure may exist by displacement wave

or other displacement characteristics. When the SUTVA does not correspond to the behavior of the data, it may render inference impossible or require additional sophisticated statistical methods [573]. The choice of an IV is often curtailed by what variables exist in a dataset. Since IVs are an artifact of how the exposure came to be assigned, they must be "found" and cannot be produced [574]. IVs tend to be rare in the real world and oftentimes, do not correspond to the exposure in one's study or violate one of the four assumptions outlined above. A central overarching consideration in selecting an IV is that it should strongly encourages exposure. In this example, we chose to create a strong IV that carved out a large percentage of the data with weak encouragement values. As we increased the strength of the IV, fewer observations were available for inference. This dynamic epitomizes the *bias-variance trade-off*—increases in accuracy come at the cost of losses in precision [575]. The construction of an extremely strong IV produced a large margin of uncertainty which may be tolerable for certain research questions and not others. In addition, this simulation emphasized how data design affects biases. We, therefore, generated a simple case in which the treatment effect was constant across subgroups to produce target parameters that were equal (i.e. ATE = ATT = CACE). Heterogeneous treatment effects likely exist within certain subgroups in the real world which presents an area of further methodological work not addressed in this paper. A GLMM would usually result in estimates that differ from those of a tailored IV estimator [550]. The GLMM targets an intent-to-treat analysis to produce estimates for all individuals without adjustment for one's compliance to exposure assignment [576]. Our study sought to isolate and explain bias reduction that could be solely attributed to design, so holding the inference step constant between full matching and Full-IV Matching was important for comparison. We forced a high level of compliance to the exposure by creating an extremely strong IV. The GLMM estimates would therefore roughly correspond with those from a tailored IV inference method. The creation of tailored

statistics for inference with an IV estimator, however, were outside the scope of this paper and would require additional mathematical proofs, particularly to calculate standard errors [577]. We explored standard errors in bootstrapping estimates, but direct calculation of the spread of the estimators is an area of future statistical development. The findings rely upon a single simulation study which would need to be replicated to determine the estimator intervals and gauge the performance of Full-IV Matching. We, nevertheless, produced a new design approach that is useful when an epidemiologist is concerned about unmeasured biases and provided code that can readily be applied using current statistical software in R.

Conclusion

Unobserved covariates can be a source of bias in inference that is both concerning and near impossible to quantify when proxy measures do not exist in a dataset [551]. We outlined a case in which the important covariate of *social capital* was not measured, and correlated proxies were not available. This situation commonly occurs in population-based surveys, including in observational studies of violence against children after internal displacement from natural disasters. In this instance, we were willing to apply a strong IV to reduce the influence of *social capital* on the estimate for sexual violence. We illustrated that Full-IV Matching served a dual purpose of tackling biases from known covariates and unmeasured biases that could not be directly addressed in adjustment. Full-IV Matching is a tool that allows epidemiologists to modulate the strength of a continuous IV to correspond with hypotheses as to the extent and influence of unmeasured biases and creates a binary structure suitable for matching on high and low values of the IV. This design is promising in increasing the rigor and accuracy of inference within population-based surveys.

CHAPTER 9: DISCUSSION AND CONCLUSION

This thesis explored the relationship between natural disasters and violence against children and sought to identify promising methodologies for future epidemiological study. In the final chapter, I summarize the principal findings of this body of work, its contributions to new knowledge, and its limitations. I subsequently outline the implications for future research on natural disasters and violence against children.

9.1 Summary of main findings

A substantial gap exists in understanding the association between natural disasters and violence against children. Current conceptual framings of violence against children operate under the assumption that violence universally increases after disaster events [93, 94, 383]. In contradiction, the global systematic review and meta-analysis in Chapter 5 suggests that a direct statistical association between natural disasters and physical, emotional, or sexual violence cannot be established from the available evidence, albeit the conclusion relies upon a limited number of studies with methodological limitations. Findings primarily from grey literature in Chapter 6 seem to suggest the opposite—an array of changes occur during and after natural disasters which may increase the risk of violence against children. Given the conflicting body of evidence, I analyzed original empirical data on the effect of one aspect of natural disaster exposure, internal displacement from the 2010 Haitian earthquake, on violence against children and developed a high-quality methodological framework for increasing study rigor. I found that displacement to either camps or communities was not associated with physical, emotional, or sexual violence for girls or boys. Sexual violence against girls and physical violence perpetrated by authority figures against boys were sensitive to potential

unmeasured biases, however. The findings from the sensitivity analyses and the challenge of addressing unmeasured biases in observational studies were the impetus behind Chapter 8. In Chapter 8, I advanced a blended design approach that can mitigate threats from measured and unmeasured biases if additional information on the study population is recorded. The chapter compared a traditional form of matching that built upon the methodological framework developed in Chapter 7 to a novel approach—*full matching incorporating an instrumental variable (IV)* or *Full-IV Matching*. I illustrated how Full-IV Matching can reduce measured and unmeasured biases which may increase accuracy in a manner that full matching cannot. Full-IV Matching is an innovative design that has the potential to increase the quality of future analyses of population-based surveys in studying violence against children after natural disasters.

9.2 Contribution to new knowledge

This thesis contributes a cohesive body of knowledge, a high-quality empirical study, and various methodological advancements to the discipline of epidemiology and field of violence research. The following section outlines the main contributions across the chapters.

9.2.1 Synthesizes the body of knowledge on natural disasters and violence against children

In this thesis, I synthesize current literature on natural disasters and violence against children into a cohesive whole. Until this juncture, to my knowledge, no overarching examination of violence against children specific to natural disaster settings had occurred within public health or other fields relevant to child protection, and the information contained within individual studies was haphazard and isolated [458, 578]. The

coalescence of information is an important step in defining the boundaries of the existent body of literature and in bringing attention to the issue. One of the most important contributions of this thesis is that it highlights gaps in the evidence. My analyses determined that the current literature is limited and has quality issues. The eleven peer-reviewed articles identified in the systematic review in Chapter 5 were mainly from the United States and did not contain expansive information on subpopulations of children, types of disasters, or all violence forms. The systematic review in Chapter 6 organized information from 26 peer-reviewed and grey literature sources into five pathways. The description of how natural disasters led to violence, however, was cursory. The included sources mainly contained summative sentences to describe complicated mechanisms and did not fully explore how violence occurred. In tracing what is not known and where the literature can improve, this thesis identifies the types of knowledge that are needed for targeted future study.

9.2.2 Refines the conceptual model of the relationship between natural disasters and violence against children

Past conceptual frameworks that explore the linkages between natural disasters and violence against children conflate natural and man-made disasters [93, 94]. The assumption is that both phenomena are similar macro-level events that produce trauma and lead to identical patterns of child abuse. As a further complication, natural and man-made disasters frequently co-occur and are statistically correlated, so it is challenging to distinguish unique effects [579]. Despite the complexity, recent research continues to frame natural and man-made disasters as equal and indistinguishable [578]. I draw from literature exclusively on natural disasters and highlight relevant theories to explain how they may lead to violence against children at multiple levels of the social ecology. While many characteristics and underlying mechanisms overlap, I delineate evidence specific

to natural disasters throughout the thesis for beginning to conceptualize how they may differ. The classification of factors to different levels of the social ecology serves another practical function; it allows for appropriate tailoring of violence prevention programs to factors at the community, relational, or individual level. The conceptual model in Chapter 3 organizes the literature from Chapter 2 which aids in thinking of which individuals or groups to engage and how to create effective intervention designs that are tailored to each level of the social ecology.

I applied the socioecological model to visualize how a macro-level event, like a natural disaster, translates into interpersonal acts of violence, but the socioecological model was insufficient in understanding pathways to violence. To unpack the mechanisms, I outlined potential mediating factors between natural disasters and violence against children in Chapter 2 and summarized the current evidence base on pathways to violence in Chapter 6. Mapping of mediators and pathways builds intellectual coherence on how natural disasters increase violence, but my discussion on moderation in Chapter 3 is perhaps the most distinct addition. I described how the meaning ascribed to natural disasters, the positive coping behaviors exhibited, and types of social support mobilized could moderate specific pathways to violence against children. In pinpointing which responses and resources buffer the negative effects of natural disasters, I identify behaviors and assets for future study that may be important in preventing violence and may serve as ingresses into programmatic designs. A better understanding of moderators of violence allows programs to adopt strengths-based approaches to support locally driven solutions to violence prevention after natural disasters.

9.2.3 Provides high-quality and nuanced empirical evidence to better understand the effect of natural disasters on violence

I advanced understanding of the quantitative relationship between natural disasters and violence against children by conducting a global meta-analysis and an empirical analysis of internal displacement from the 2010 Haitian earthquake. The meta-analysis in Chapter 5 contradicted currently held assumptions, suggesting that a universal and direct relationship does not exist between natural disasters and physical, emotional, and sexual violence, but additionally, illustrated that informational gaps and quality issues exist which may affect conclusions [93, 578]. The lack of representative coverage across regions, disaster types, and subpopulations of children challenged inference about overall effects. The evidence, moreover, suffered from inconsistencies in operational definitions of violence and clear temporal ordering of exposures before measured outcomes. The state of the evidence implies that higher quality research should be conducted to generate conclusive results.

I analyzed nationally representative survey data on internal displacement from the 2010 Haitian earthquake in Chapter 7 to expand the evidence base and to address several quality issues exhibited by the included studies in the prior meta-analysis. The analysis targeted causal estimates for how internal displacement led to long-term physical, emotional, and sexual violence against girls and boys. My findings increased understanding of the effect of one aspect of natural disaster exposure, internal displacement, on violence against children which may be comparable across other settings. It, furthermore, highlighted that sensitivities to unmeasured biases were possible. Although most results were robust and suggested that internal displacement from the earthquake was not associated with long-term physical, emotional, or sexual violence against girls and boys, sexual violence against girls and physical violence perpetrated by

authority figures against boys were sensitive to potential unobserved covariates, meriting further exploration.

Since conducting my analyses, several recent studies have explored the effect of natural disasters on violence against children. Population-based survey data from Lesotho linked drought to a three-fold increase in transactional sex among girls between 15 and 19 years of age but not to forced sex [9]. Transactional sex is a form of exploitation that may mediate future sexual violence and mask a direct association between natural disasters and violence against children [580, 581]. In addition, two studies detected increases in violence against children after natural disasters. The death of a household member during the 2010 Haitian earthquake was associated with increases in emotional and severe physical abuse against children in a nationally representative survey [582], and the first wave of data from a nationally representative longitudinal study in the Philippines found that exposure to natural disasters was associated with higher levels of recent family violence and physical abuse of children [583]. Although sampling adult women, a relevant study from 2020 in Australia also highlighted that the odds of violence against women increased in areas that were highly affected by bushfires and where household income decreased [584]. The collective findings point to the complexity of the associations. Natural disasters likely do not exert a consistent effect across all typologies of disasters, populations, timeframes, or forms of violence. Similar to the findings of no clear directional effect or association in the meta-analysis conducted in Chapter 5, grouping diverse phenomena and measurements under the umbrella of natural disasters and violence against children may mask true effects. The inclusion of different factors within analyses is equally important. The study of drought in Lesotho, for instance, showed no effect when transactional sex and violence were jointly analyzed but identified increases in violence when transactional sex was analyzed separately [9]. The variability

in the definition of exposure likewise impedes identification of the aspects of natural disasters that are most meaningful in driving violence. No more clearly is this illustrated than in comparing three nationally representative, cross-sectional studies of violence against children after 2010 earthquake in Haiti. Subedi et al. [585] found no association of violence when distance to the earthquake epicenter was used as a measure of exposure, corresponding to findings on internal displacement from the earthquake in my analysis in Chapter 7 [507]. However, when exposure to the earthquake was defined as death of a household member, an analysis that relied upon the same dataset detected increases in emotional and physical violence against children [582]. The divergent findings suggest that choices in one's definition of natural disaster exposure can produce profoundly different results and is described in greater depth in Section 9.3.3.

9.2.4 Defines pathways by which violence against children may occur in natural disaster settings

The collective evidence indicates that a complex network of indirect pathways lead to violence against children. This thesis compiles relevant literature to suggest where information is absent and organizes identified pathways into a tentative mapping of how violence increases after natural disasters. In Chapter 6, I thematically grouped the evidence into five pathways to violence, including: (i) environmentally induced changes in supervision, accompaniment, and child separation; (ii) transgression of social norms in post-disaster behavior; (iii) economic stress; (iv) negative coping with stress; and (v) insecure shelter and living conditions. I further describe how the process of charting pathways to violence against children can be used in determining meaningful junctures for the design of targeted interventions and programming.

A seemingly growing number of studies are exploring pathways from natural disasters to violence against children. A recent qualitative study on violence against women and children in households after Hurricane Matthew identified a number of pathways that correspond to those outlined in this thesis, such as economic insecurity and social norms [233]. Likewise, a notable study from Haiti analyzed 265 narratives exploring reasons for sexual relationships between UN personnel and women and girls during and after the 2010 earthquake and found that the poverty and vulnerability of the affected population, unequal power dynamics, and lax disciplinary action for protocol breeches led to consensual and non-consensual sex [586]. Following a similar pattern to the literature outlined in Chapter 2, recent studies tend to examine intermediary factors on the causal pathway to violence, rather than outline complete pathways from natural disasters to violence against children [212, 587–590]. This thesis assembles the broader literature into a mapping of pathways, but information is still relatively limited in the disaster literature and does not clearly identify how violence occurs. Furthermore, multiple methodological challenges exist which are described in the subsequent section.

9.2.5 Advances rigorous methodological approaches tailored to observational datasets and the study of natural disasters and violence against children

Quantitative studies that examine the effect of natural disasters on violence against children commonly rely upon measures of association which leave unresolved questions about temporality and causation [101, 534, 591]. I embarked on an effort to adapt a methodological framework for analyzing observational data with increased rigor in Chapter 7. This framework outlined the types of data structures in population-based surveys that need to be collected in order to conduct causal analyses (i.e. covariates that are collected or designed as occurring prior to exposure and outcome measures that clearly occur after exposure) and provided a schema for data analysis with matching

methods. The data structures and suite of matching-based methods are promising in increasing the quality of future studies on violence after natural disasters, particularly in resource scarce settings where cross-sectional surveys are often the best available option for collecting data on the affected population. I additionally extended discussion beyond traditional matching methods in illustrating the utility of a novel design approach, *full matching incorporating an instrumental variable (IV)* or *Full-IV Matching*, which can mitigate threats from measured and unmeasured biases. I created a synthetic dataset for a simulation study in Chapter 8 by generating data similar in structure to the VACS analyzed in the prior chapter and built a suitable instrument to compare bias reduction and accuracy between full matching and Full-IV Matching [570]. Full-IV Matching most reduced biases from observed and unobserved covariates and produced the most accurate estimate in this simulation which provides a proof-of-concept for further generation of simulations to evaluate its performance. I emphasized that incorporation of an IV in pre-processing data provided a transparent means of assessing the quality of the IV to increase methodological rigor. It is currently commonplace to include an IVs as part of inference, so this alternative usage of IVs can benefit the field of epidemiology [551, 553]. I also support dissemination and practical application by sharing useable code, as current statistical packages do permit full matching with IVs [449–451]. My hope is to build upon this simulation to advance future epidemiological analyses of population-based surveys, with a particular lens on studies of violence against children in natural disaster settings.

Recently published papers apply regression-based statistics mainly to cross-sectional datasets in analyzing the relationship between natural disasters and violence against children [9, 582, 584]. As such, they use a different approach and make different assumptions than the matching-based methodologies that I apply in Chapters 7 and 8. The tradition of matching within observational datasets attempts to model itself after

experimental design in that researchers blind themselves to the outcome to avoid biases and design a "study within a study" to test a hypothesis [554]. The focus is thus on increasing internal validity [103]. Matching-based approaches to observational data cannot achieve the level of internal validity as results from a randomized experiment, but the emulation of experimental design clarifies the minimal assumptions necessary for making causal claims; attempts to reduce the number of assumptions made in one's design; and creates data structures that are more compatible with those used for inference in an experiment. In contrast, regression-based techniques attempt to extrapolate to a general population and within cross-sectional data, generate correlations rather than causal estimates [547, 592]. This thesis attempts to move the quality of the evidence on this topic towards a high-quality experimental design. I propose a methodological framework in Chapter 7 which calls for differentiating pre-and-post changes in background covariates in cross-sectional surveys for matching and develop a Full-IV Matching design in Chapter 8 that can reduce the influence of measured and unmeasured biases. These approaches are a step forward within my topical area of violence studies and more generally, in the analysis of observational data.

9.2.6 Summary of main contributions

My findings collectively contribute to a better understanding of the complexity of the relationship between natural disasters on violence against children. Assumptions exist that natural disasters increase violence against children, but no systematic study had examined the evidence underpinning this specific relationship [458, 578]. I brought together the current literature to identify gaps in knowledge and refine a conceptual model of natural disasters as a distinct form of humanitarian emergency. The socioecological model provided a useful schema in organizing concepts and identifying the level at which elements of the post disaster environment might lead to violence, but documentation of

mediated pathways and moderators added an extra dimension in understanding how and why violence may occur. In particular, the possible differences in moderation between natural and man-made disasters is a promising area of future study and programmatic design for violence prevention. I built original analyses by empirically testing the associations between natural disasters and violence against children in a meta-analysis and secondary data analysis of internal displacement from the 2010 Haitian earthquake and subsequently, traced pathways to violence in a systematic review of the literature. Quantitative testing sought to determine if a direct relationship existed, with internal displacement as one aspect of exposure. The mainly qualitative compilation of pathways complemented the statistical analyses in identifying indirect routes to violence and factors that might be important targets for future violence prevention programming. The summation may seem that a direct relationship does not exist and that indirect pathways are probable. This statement requires qualification since differences likely exist across regions, disasters, populations, and violence types. The clear temporal ordering of exposure before outcome measures in past studies further challenges effect estimation. I sought to apply and disseminate methodologies that have the potential to avoid many of the pitfalls of current research. To this end, I outlined a methodological framework for measuring violence after natural disasters in resource scarce settings with cross-sectional surveys and developed a method that can reduce potential biases from observed and unobserved covariates, which commonly threaten the validity of observational studies and would be likely in studying the effect of natural disasters on violence against children.

9.3 Limitations

This thesis is not without limitations. I previously described specific limitations that relate to each research chapter. In this section, I frame several overarching limitations of this thesis.

9.3.1 Evidence gaps in information on natural disasters and violence against children

A driving force behind the creation of this thesis is also its greatest weakness—the paucity of academic evidence on natural disasters and violence against children. In Chapter 5, a global systematic review identified a meager eleven peer-reviewed articles that measured the association between natural disasters and violence against children, and I found nine publications from academic journals in the systematic review described in Chapter 6. Clearly, a gap exists in the literature which impedes nuanced study of differences across disaster types, populations of children, regional and sociocultural differences, and violence forms. It may be that violence manifests differently in certain settings or decreases under conditions which could not be explored thoroughly. Natural and man-made disasters frequently co-occur, and the occurrence of one precipitates the other [579]. The evidence largely did not apply the appropriate study designs to capture differences and correlations between natural and man-made disasters or test how each affected violence against children. This thesis sheds light on a small section of the dynamics and variations that could occur in studying this topic.

Quality issues in the reviewed studies and the exclusion of important demographics and experiences in the Haitian dataset hindered analyses and may have led to biases in estimates. The systematic reviews and meta-analysis described in Chapters 5 and 6

present effects and pathways to violence for the general population of children. It is likely that certain populations of children are at higher risk of violence after natural disasters because of preexisting vulnerabilities which could have been isolated in stratification if the studies had collected more granular information on group membership. Relatedly, the dataset analyzed in Chapter 7 did not include two important variables which may have influenced violence outcomes—socio-economic status and place of residence before the earthquake. Low socio-economic status is an ongoing stressor that increases the risk of child abuse, and natural disasters disproportionately affect the poorest children and families by causing a catastrophic loss in income and employment opportunities [220, 511, 521]. Place of residence is important, both as a source of differential risk of child abuse and as an instrument that can be used to reduce selection bias in exposure [319, 546, 593]. These variables hold in common that they are associated with risk, but an array of protective factors likewise were not included in the data. Affected populations may possess resources or have characteristics that protection children from violence after natural disasters. The focus on risk across the data analyzed in this thesis reflects wider trends in violence research, whereby a disproportionate amount of information is collected on risks rather than strengths [594]. The analysis of secondary data always is constrained by what information is included in the dataset, and I attempted to maximize the data and perform the most robust analysis possible within the limits of the data structure.

9.3.2 Determination of causation

The gold standard in determining causation is a prospective randomized experiment, epitomized by a randomized controlled trial (RCT), because it scientifically tests a hypothesis with a resulting high internal validity [595]. Observational data are unlikely to meet the specifications of experimental design, and the data analyzed in the research

chapters of this thesis are no exception. A full understanding of potential limitations requires further dissection of how experimental design determines causation. One of the greatest strengths of experimental design is the fact that treatments are randomized. Randomization strives to produce individual units within treatment and control groups that have identical covariate distributions and potential outcomes which targets the Average Treatment Effect (ATE) when calculated for multiple individuals within each study arm of the experiment [103]. Any difference between treatment and control groups is therefore due to chance. A researcher cannot randomly assign a child exposure to a natural disaster or internal displacement for ethical and logistical reasons. The lack of researcher control in the assignment of an exposure, however, entails a certain level of imperfection in exposure probability between exposed and comparison groups that cannot be overcome in the real world. Natural disasters present a unique opportunity, because they act as natural experiments that assign exposure near randomly on the population level, even if patterns of exposure are in-part defined by geographic location and weather. The conditional independence of the exposure reduces biases that would be present in other studies of social phenomena [537]. I maximize this characteristic of natural disasters in Chapter 7 by way of design choices. In extending further, I incorporate an instrument as part of the simulation study in Chapter 8 as a feasible means of reducing deviations from randomness to a greater degree. I still did not determine assignment to the exposure which entails that the mechanism is not completely understood or at random in the sense of a controlled experiment.

A second benefit of experimental design is that it recruits individuals based upon set criteria. Careful recruitment into experiments serves to balance background covariates, reducing the probability of confounding and increasing comparability between individuals within the treatment and control arms of the study [596]. Confounding arises

from what Rubin [597] refers to as a lack of *ignorable treatment assignment*, or in other words, a dependency between the exposure and the potential outcome. Individuals are not purposefully assigned to exposures in the real world, and it is likely that characteristics or experiences will influence exposure likelihood. In extreme cases, members of an exposed and comparison group will completely differ, and observational units between groups are therefore nonexchangeable and incomparable. I carefully designed my data in Chapters 7 and 8 to increase exchangeability between exposed and comparison groups by balancing their background covariates before earthquake exposure. Although several techniques exist, this approach moves closer to testing causal effects than regression-based modeling of a cross-sectional dataset [597].

The final benefit of experimental design is its prospective data collection. Prospective design in experiments, repeat panel data, or longitudinal studies permit the researcher to track the time ordering of variables and avoid recall biases in response [598]. The data analyzed in this thesis are cross-sectional. Adjustment of covariates that are affected by the treatment generally lead to biased estimates [592]. In cross-sectional surveys, the covariates and exposure are measured at the same time point which presents problems in parsing out how covariates change as a result of the exposure. For this reason, I isolated covariates that were reported as occurring before exposure and utilized them within matching algorithms in Chapters 7 and 8. The creation of pre-exposure covariates based upon reporting is nevertheless imperfect as compared to a prospective study.

An inherent feasibility issue, moreover, exists in applying prospective study design for the study of the relationship between natural disasters and violence against children. By chance, data may have been collected before a natural disaster to determine a baseline and stave off potential biases, but frequently, it is not the case. The exact location of a

future natural disaster can rarely be predicted with sufficient advance warning and accuracy to employ a prospective design [599, 600]. Given the challenges and constraints of data collection, most data structures are likely to be cross-sectional, and the matching-based designs that I applied in Chapters 7 and 8 are warranted to reduce potential biases to the greatest extent possible.

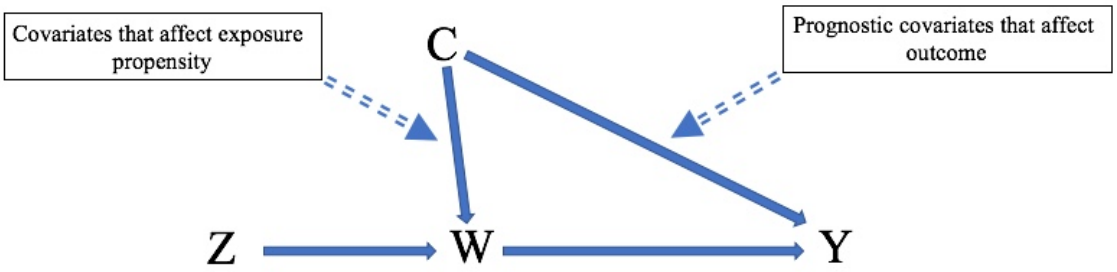

Figure 12. Directed acyclic graph of causal relationships

W = exposure, *Y* = outcome, C = confounder, and *Z* = instrument.

9.3.3 What is exposure?

A challenge of measuring the association between natural disasters and violence against children is disentangling what constitutes exposure. One issue is defining exposure. No universal definition of natural disaster exposure exists, and there is a certain amount of variability by disaster type [73]. By way of an example, temperature may be the most salient measure of a drought, but seismic magnitude may be a better measure for earthquake intensity. Within other natural disasters, several types of measurements could determine exposure (e.g. hurricane wind speed or rainfall). A second issue relates to defining exposure on the individual or community level. Both individual and community level markers of exposure are vulnerable to measurement error. The most meaningful measures of exposure on the individual level are unknown, and commonly used, self-reported disaster experience scales ask questions on varied aspects of exposure which are likely sensitive to recall bias [73, 601, 602]. A common alternative approach is to define

exposure by geographic region, but this practice suffers from a type of ecological fallacy. Aggregate spatial determinations of exposure overlook that individuals have a multitude of different experiences during a disaster event and that the intensity of exposure varies within affected regions. One person may witness the death of family members, while another watches a strong storm from the safety of his or her living room. The variability yields dramatic differences, even across similar types of disasters [366, 543]. Furthermore, several possible causal mechanisms exist by which an exposure or multiple exposures could lead to violence against children. It may be that exposure to one disaster event is necessary and sufficient to produce violence, or exposure may need to occur during a critical time period. Multiple exposures may accumulate to produce worse outcomes, or exposure may be enhanced or diminished by subsequent exposures [603]. On the community level, the actual boundary of where a natural disaster ends may be unclear. A gradient may exist, with certain micro-locations affected to a greater degree than others. Without a strong compass to guide determination of what is an exposure and how it behaves, I applied an inclusive definition as any form of exposure in my meta-analysis and systematic review in Chapter 5 and 6. This choice may have blurred differences across studies within these chapters, but an insufficient breadth of studies existed to stratify further by exposure type. Internal displacement to any location in Chapter 7 and to a camp setting in Chapter 8 were respectively utilized as markers of earthquake exposure. I selected these exposures based upon careful thinking about the aspects of exposure that would be meaningful and specific in producing violence and that were available in the dataset. The use of earthquake damage level as an instrumental variable in Chapter 8 further teased out bias in an unobserved covariate that could have led to differences in exposure probability, but still, it was an imperfect instrument.

9.3.4 Missing mediation

The analyses applied in this thesis focus on testing the direct effect of natural disasters on violence against children, but what if all effects were mediated by intermediate factors that were not observed? Spurious associations can result from a lack of fixing mediators, and a full or a strong partial mediation would mask a direct effect of natural disasters on violence against children [500, 604, 605]. The studies synthesized in Chapter 5 provide limited and contradictory descriptions of mediators—structural equation modeling indicates that PTSD resulting from exposure to Hurricane Katrina completely mediated emotional bullying behaviors, while hierarchical modeling found that PTSD did not predict emotional or physical bullying [152, 475]. I grouped the mainly qualitative studies in Chapter 6 into five general pathways that could have led to violence against children after natural disasters, but likewise, the majority of the evidence centered on negative coping with stress and related mental health conditions. The studies identified in the systematic review did not equally document information for all pathways, and their relative importance was not measured. In Chapters 7 and 8, the cross-sectional data structure hindered disentangling of mediators on the pathway between natural disasters and violence. Although temporal ordering of variables does not guarantee that spurious relationships are eliminated in a dataset, it aids in isolating plausible mediation which is challenging in cross-sectional surveys [605]. I more broadly chose to apply a hypothesis confirmatory approach, rather than an exploratory design to model mediated relationships. This approach cannot easily disentangle complex mediated relationships between variables. The gap in information, however, spurred my investigation of this topic [93, 453]. Mediation would best be explored as our foundation of empirical knowledge develops and greater articulation of hypothetical pathways occurs.

9.3.5 Moderation of violence

The strength of the association between natural disasters and violence against children may be moderated by factors that are not captured in my thesis. Individuals, families, and communities respond to natural disasters in ways that may reduce or heighten the risk of violence [606, 607]. Moderated analysis would illustrate coherence between theories and empirical evidence and isolate changes in specific groups. Similar to mediation, the state of the evidence on natural disasters and violence against children is nascent, and analyses of moderation necessitate a prior articulation of how moderation occurs which has not yet occurred. I attempt to highlight mechanisms by which moderation possibly occurs in the background discussion sections of this thesis, even though my analysis is mainly focused on understanding how natural disasters produced violence and on testing statistical associations. Within the research chapters, I included discussion of moderation and interaction terms when possible. The meta-analysis in Chapter 5 did not contain sufficient information to analyze differential effects by moderation. Four qualitative studies from the systematic review in Chapter 6 highlighted how restricted movement of girls, changes in travel patterns among children, and indigenous coping mechanisms may reduce violence after natural disasters, but the explanations were tentative and not described in sufficient depth to understand fully how each behavior affected violence [480, 482, 484, 493]. Individual and community moderators were not collected in the Haitian dataset that was analyzed in Chapters 7 and 8. I did not include interaction terms in Chapter 7 as a caution against introducing additional biases without sufficient empirical knowledge but incorporated plausible interaction terms in Chapter 8 to diversify data structures and acknowledge the importance of interactive effects for future analyses.

9.3.6 Temporal patterns of violence

A critical element that could not be explored in this thesis is when violence against children occurs in the post-disaster environment. The respective systematic reviews described in Chapters 5 and 6 captured two studies in which violence was a short-term phenomenon that spiked in the weeks or months after a disaster event [66, 479]. The central dataset analyzed for Chapter 7 documented violence in the 14 to 16 months after the 2010 Haitian earthquake [427]. As a result, my analysis may have failed to detect short-term increases in violence. Natural disasters also may change the physical environment and structures of human relationships in a manner that leads to increased violence risk over time, and long-term patterns of violence may differ than those in the immediate post-disaster time period. The matching-based designs applied to the original analyses in Chapters 7 and 8 are not well-suited to understand dynamic changes in the environment and longitudinal synergies among risks. Rather, I chose a statistical approach to improve internal validity and move closer to experimental study design, given the potential biases inherent in observational datasets [103].

9.3.7 Measurement error and reporting misclassification of violence

Measurement error and reporting misclassification are inherent in violence studies and would be likely sources of bias in Chapters 5, 6, and 7. Measurement error results from inaccurately identifying the existence, nonexistence, or extent of violence and relates to the validity of the study's measurement metrics [548]. The systematic reviews in Chapters 5 and 6 combined studies that used variable measures of violence with differing quality. The included studies would inevitably have missed a proportion of violence cases, because they did not universally measure all behavioral acts or typologies of physical, emotional, and sexual violence. The violence measures in Chapter 7 likely were highly accurate since the survey questionnaire was field tested in a qualitative pre-study to

ensure that the most important types of violent acts were measured, that the respondents understood the questions, and that the violence terms were properly translated into Haitian Kreyol [436]. Specific acts of violence were still missed, such as physical or emotional bullying from other children, which would have led to an underestimation of violence [427].

Reporting biases relatedly lead to inaccuracies and misclassification of cases of violence. The age and developmental capacity of the child are important factors that impact self-reporting. Younger children or those with a lower stage of development are likely to underreport violence, given their limited awareness of what constitutes abuse, an inability to report (i.e. the child's language capacities may not be formed), and a dependency on the abuser [83, 84]. In addition, violence is stigmatized in any setting which leads to further underreporting and misclassification [81, 82]. Memory likewise impacts misclassification. Experiences of violence can be traumatic, leading to inconsistent remembrance of events, or recall bias, and underreporting [86–89]. An alternative form of data collection relies upon informants, but it probably yields greater inaccuracies in reporting. Service providers, teachers, and other adults do not detect all cases of violence, and paradoxically, caregivers are likely to know about abuse in the child's home but are unlikely to report, as they are often the perpetrators [137]. Meta-analyses have found that estimates generated from child self-reports of violence are over 30 times higher than informant reporting for sexual violence and 75 times higher for physical violence [134, 135]. The data analyzed in this thesis was mainly self-reported by children. One would conjecture that the resulting estimates are more accurate than those that rely upon detection and reporting by an external respondent and that nearly all reporting misclassification leads to underestimation of violence.

9.4 Implications for future research

In this section, I will highlight opportunities for future research, based upon the findings of this thesis.

9.4.1 Greater formative research on natural disasters

The central analysis of this thesis empirically tested the relationship between a measure of exposure to one type of sudden-onset natural disaster and violence against children. Scientific experiments require replication to draw conclusions. After multiple trials with different populations, one likely can infer causation and define patterning. In other words, many more studies are needed to understand the overall effect of natural disasters on violence against children. This thesis calls attention to the need for greater study. Complementarily, it highlights the need for quality evidence. As a burgeoning area of investigation, each low-quality study has the potential to skew the limited evidence base. Incorrect conclusions can lead to investment and programmatic design that inadvertently harms children. It is of upmost importance that future research fastidiously applies rigorous methodologies to build a solid foundation of knowledge.

The evidence base should grow to better understand differences between slow- and rapid-onset natural disasters and repeat climatic events. A drought that develops slowly or a recurring tropical storm may yield unique social dynamics and as a result, different patterns of violence. Future research should seek to explore and contrast different types of natural disasters and adapt methodologies for each typology. Within each type of natural disaster, ample leeway exists to examine differences by gender, subpopulation of children, perpetrator, and form of violence. Furthermore, stressors may interact, or stress

thresholds may exist that are meaningful in the realization of violence, meriting further study [73].

Greater understanding is needed of how to measure exposure to natural disasters and of the aspects of exposure that lead to violence. I used displacement status as a clear indicator in Chapters 7 and 8, but other measures, such as witnessing the death of loved ones, may be highly predictive of violence against children. Further research should decompose exposure into various elements and test which aspects are most salient for the study of violence. In terms of multiple exposures, quantitative testing of hypotheses may shed light on if the accumulation of exposures or an exposure during a critical period produce different violence patterns. This potential direction for future research corresponds with a need to collect repeat measures with a large cohort to ensure that sufficient data exists to model and test each possible trajectory [603].

It merits noting that the study of violence should be appropriately placed within the overarching dynamics of humanitarian emergencies. Natural disasters often lead to high levels of infectious diseases and other negative health outcomes that need to be prioritized for survival [608–610]. On the other hand, violence against children is a "silent epidemic" that cannot be negated and leads to mortality, morbidity, and other markers of poor development [36, 129, 611]. These issues do not exist in siloes, as implementation of a humanitarian response without a protection lens may inadvertently exacerbate violence [341]. This thesis speaks to the importance of understanding natural disasters and violence against children, but a broader tension exists in where to invest when time and resources are constrained. I do not purport to offer answers to the appropriate structure or balance of programmatic investment but suggest that future analysis must be couched within intersectional discussions of how humanitarian response can lead to violence and

consider opportunity costs of investment in violence research and programming when they come at the expense of other health priorities. The hope would be that investment matches need which is all the more reason to understand the magnitude and scope of violence against children after natural disasters.

9.4.2 Integration of the pre-disaster context

The historical and sociopolitical context in which natural disasters occur may be important in determining violence prevalence after natural disasters. It may be that children experience more violence in places that lack robust systems of protection or where traditional social safety nets are eroded. This point is salient given that natural disasters disproportionately affect low- and middle-income countries where social services may be limited [112]. These settings, therefore, should be a research priority. Locations that experience natural disasters also frequently have man-made disasters, and their occurrence is correlated [579]. Carefully designed studies should tease out differences in the causal effects of each ecological phenomenon and any possible compounded effects so that researchers can identify situations that pose the greatest risk for violence against children. These findings will have implications in determining the design and scale of future humanitarian child protection programming.

9.4.3 Incorporation of key variables in future investigation

Insights from this thesis and the existent literature indicate that future studies should incorporate additional variables to increase internal validity. Individual level measures of children's place of residence prior to the natural disaster; past exposure to natural disasters and internal displacement; and mental health before the disaster event are important factors that may bias the relationship between natural disasters and violence against children. Important relational or household measures that should be collected and

incorporated into future analyses include caregiver mental health disorders before the disaster event; caregiver or sexual partner's past problematic substance use; and familial socio-economic status prior to the natural disaster. On the community or regional level, receipt of humanitarian aid, levels of policing, and sociocultural norms are some examples of the type of information that would assist in better isolating differences in effects. These variables could be incorporated in analyses as covariates and in some instances, serve as instruments. Post-disaster measures of several of the abovementioned variables would likewise be applicable for consideration as mediators or moderators.

Table 12. Potential key variables for future data collection

Level of social ecology	Examples of key variables	Potential data sources
Individual	1. Child's prior place of residence 2. Child's past exposure to natural disasters 3. Child's past internal displacement experiences from natural disasters 4. Mental health disorders of the child before the disaster event	Survey questionnaires Logbooks for IDP camp registration Cell phone data Satellite imagery
Relational and household	1. Mental health disorders of the caregiver before the disaster event	Survey questionnaires Health records Police records

	2. Caregiver or sexual partner's past problematic substance use 3. Familial socio-economic status prior to the natural disaster	Records from micro-finance programs
Community	1. Community or regional receipt of humanitarian aid 2. Community or regional levels of policing 3. Community or regional sociocultural norms	Survey questionnaires Mapping of national and international humanitarian aid programs Records of humanitarian coordination committees Police records

Future research must carefully consider which variables are selected as instruments and if they are appropriate for the research question, as weak instruments will likely lead to greater biases [577]. Strong instruments are exceedingly rare and cannot be created but rather, are discovered as being suitable for use [553]. Researchers must also consider the kind of causal effect that they want to target. Most matching methods strive to estimate population level effects on all individuals (the ATE) or on the treated (the ATT). The choice of a target parameter largely depends on the research question and which variables are available in the dataset [433]. Analyses that incorporate IVs often target a subset of people whom respond to a pseudo-randomization (the CACE). The inclusion of an IV aids in sorting individuals by their treatment status to better isolate a causal effect but only among so-called "compliers"—individuals whose intervention type is largely determined by the IV. The IV, therefore, does not affect individuals that would always or never take the treatment [549]. In this manner, studies that incorporate instrumental variables usually have an implied assumption of heterogeneous treatment effects and, in

such a situation, would yield different estimates than those that target an ATE or ATT, even when analyzing the same dataset [553]. Any research that uses IVs must think carefully about the utility of the targeted parameter for the research question.

9.4.4 Better understanding of causal mechanisms

Careful identification and testing of pathways between natural disasters and violence against children is needed. This thesis outlined the evidence for probable pathways in Chapter 6, but the relationships have not been empirically validated. A goal of future research should be to clarify pathways between natural disasters and violence against children, test the strength and interactions among mediators, and incorporate moderators. As more information is gained about the relationships between covariates and the full scope of factors that may bias associations between natural disasters and violence against children, indirect pathways to violence should be explored quantitatively. Variations on inverse probability weighting of marginal structural models and the *g*-computation formula by itself or in structural nested models have been suggested to parse out indirect effects, and these methods can be developed with increasing sophistication to understand multiple mediators over time [612–615]. Effect modification can be explored using similar approaches, such as the inclusion of stabilized inverse probability weights which calculate the numerator as a function of the baseline covariates [613]. Increased understanding of these dynamics would allow humanitarian actors to build child protection programming that better counteracts risk factors before violence occurs.

9.4.5 Increased focus on identifying strengths

This thesis uses a vulnerabilities lens to frame and measure the effect of natural disasters on violence against children. An equally important question is what are the factors that prevent violence after natural disasters? Communities have lived with natural disasters

throughout time and in many regions of the world, developed indigenous coping strategies to support each other and their communities [459, 616]. Natural disasters may present opportunities for communities to come together, to redefine norms, and to assert stronger community identities. A starting point in programmatic design may not be a vulnerabilities paradigm, but rather, an ethos that is defined locally and based upon ideas of rebuilding a better society. The identification of factors that are protective or moderate violence is important in designing programs to bolster strengths and could be replicated across numerous settings. In particular, interventions that build social support as a "potentially modifiable protective resource" are promising in fostering positive parenting within families affected by humanitarian emergencies and displacement (Sim et al. [617], p. 676).

9.4.6 Greater emphasis on temporality

A major question about when violence against children is probabilistically likely to occur after natural disasters still remains. It may be that violence risk peaks shortly after a disaster event and decreases over time which necessitates a swift humanitarian response [66, 507]. Natural disasters can conversely produce delayed increases in violence [242, 244, 420]. Delayed violence increases may occur for a variety of reasons. Exposure may lead to individual level changes that do not manifest immediately. For instance, a subsection of individuals that experience natural disasters and other traumatic events exhibit delayed PTSD symptomology and therefore, may have increased risk for violence perpetration long after a natural disaster [266–268, 618, 619]. Other natural disaster exposures may occur at a critical time point, particularly among children, which increase later violence perpetration and risk [164, 165, 620]. Concomitantly, natural disasters can produce changes in the environment which intensify violence risk over time. Individuals that live in communities with effective systems of policing and trust may experience

cognitive dissonance when they view the humanitarian response as inadequate or interpret community or individual actions as problematic, given their expectations [66, 294]. They may then lash out against children when overwhelmed. In contrast, communities that have underdeveloped systems of protection would likely require a higher threshold of structural inequality and stressful events to be reached before changes are detectable from pre-disaster levels. A caveat to this statement would be if programming ceased to exist due to the natural disaster, producing a void in already limited service provision. The former would likely produce a delayed temporal patterning of violence as time progressed, whereas the latter might produce either short- or long-term manifestations of violence (refer to Figure 13 A-D for illustration of hypothetical patterns).

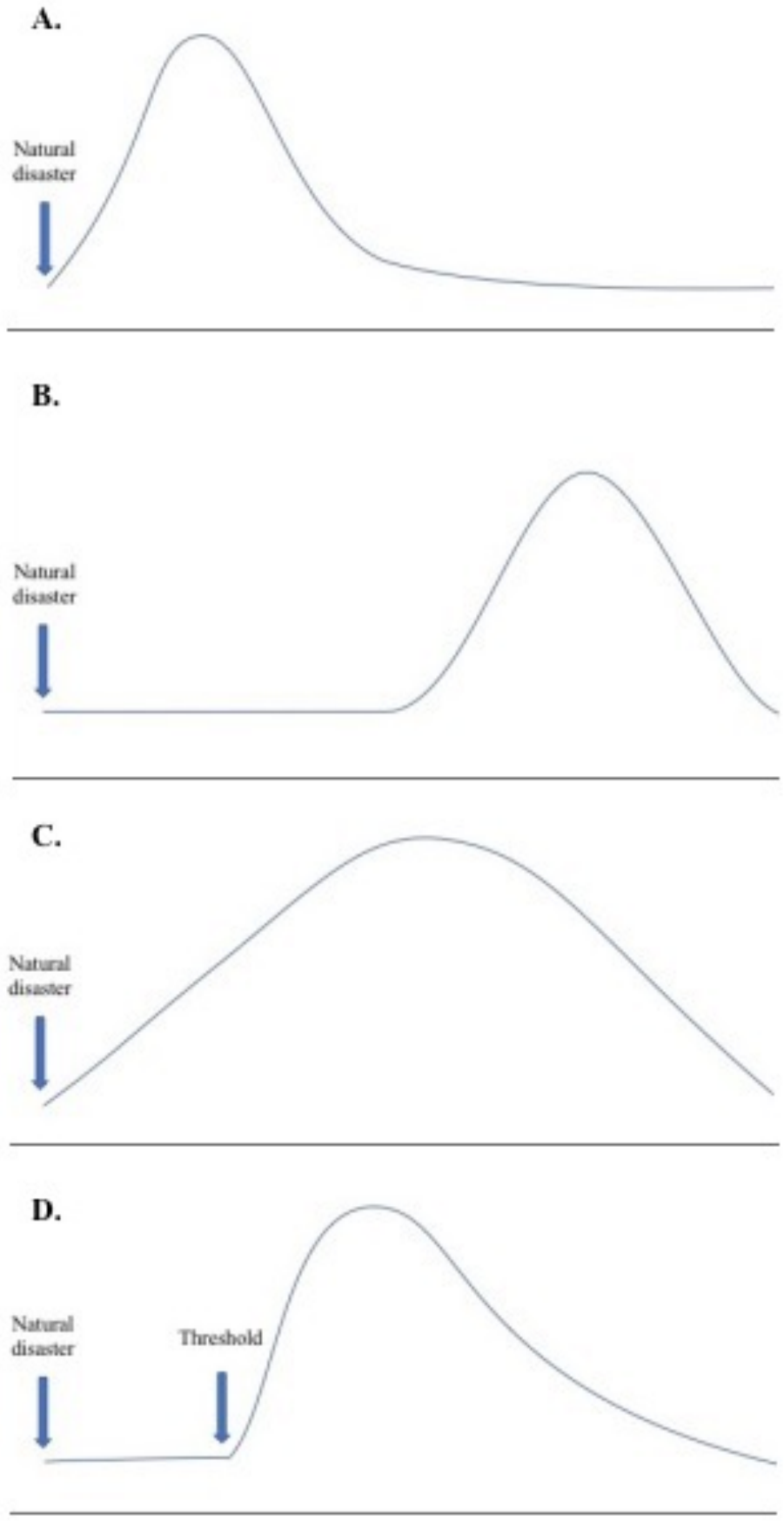

Figure 13. Hypothetical patterns for increases in violence against children after natural disasters

Figure 13-A illustrates a direct and immediate increase in violence after a natural disaster. Figure 13-B is a representation of a delayed manifestation of violence after individual level or environmental changes. Figure 13-C indicates an increase in violence as risk accumulates over time. Figure 13-D indicates a pattern where a threshold of risk is reached after which violence increases. The figures illustrate potential patterns and are not meant to indicates actual slopes or initial or final levels of violence before and after natural disasters. These visualizations are based on an exposure at one time point. Multiple exposures would likely yield different patterning.

Programmatic designs commonly adopt a trauma-based approach for violence prevention after humanitarian emergencies which focuses on short-term negative reactions to the disaster event. Humanitarian response would need to implement considerably different programming if violence was primarily driven by delayed violence responses or new structural inequalities and risks in children's environment. These programs might adopt a structure reminiscent of stable settings and be based upon interventions used in international development. Programs would need to implement a swift response if a linear pattern of violence existed after natural disasters but could potentially delay response if a certain threshold of change was needed before violence against children increased for most children. A caveat would be that service provision should not be delayed if vulnerable subgroups require immediate assistance.

The methodologies piloted in Chapters 7 and 8 of this thesis are particularly useful in parsing out violence that may increase directly after a disaster event. Specific to the study of temporal trends, several promising methodologies exist [621], but it bears mentioning that longitudinal study design is often difficult in settings that have widespread social disruption and limited resources. Research without the possibility of service provision for affected children is ethically opaque. A balance should be struck between feasibility and the need for further information of which targeted cohort studies can be devised in high-

income countries and then expanded upon in a selected number of low- and middle-income countries where a sufficient level of service provision exists.

9.5 Conclusion

I began this thesis with a quote by Michel Lechat on the importance of better understanding the public health impacts of natural disasters and a call for epidemiologists to study these complex relationships. I return again to this speech to frame my conclusions for Lechat's words encapsulate the spirit of this thesis. Lechat [1] asserts that epidemiology has the potential to do more than any other discipline to improve conditions for disaster-affected communities. In other words, research that uses rigorous methodologies to identify disease patterns and causal agents is the best means for improving human health after natural disasters. This thesis coalesced existing evidence to better understand how and why violence occurs following natural disasters. I then rigorously tested the hypothesis that natural disasters increase violence against children in a natural experiment using the 2010 Haitian earthquake and compared methodologies to reduce biases and improve future evidence. By applying a structured epidemiological approach, I sought to make explicit assumptions of universal increases in violence after natural disasters and establish a greater foundation of evidence. I laid bare that violence may not increase for the vast majority of children but also underscored how much further the research must progress to fill informational gaps. As such, this thesis contributes to and promotes greater epidemiological study for better pinpointing which populations and elements of a natural disaster present the greatest risks to children. The future replication of high-quality epidemiological research and expansion to other relevant research questions will provide information that is fundamental in structuring effective violence prevention for children. My conceptual framework highlights that future violence

prevention efforts will need to target factors at different levels of the social ecology after natural disasters to be effective. I secondarily sought to create methodological approaches tailored to natural disasters in resource constrained settings where children may be at high risk of violence. In producing rigorous methodologies, I attempted to harness the power of epidemiology to produce high-quality evidence that can be used in challenging contexts. My hope is that these tools will provide better information to prevent violence and improve health for a segment of the world's population that is often overlooked in research.

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APPENDICES

Appendix A. LSHTM ethics approval and amendment

London School of Hygiene & Tropical Medicine
Keppel Street, London WC1E 7HT
United Kingdom
Switchboard: +44 (0)20 7636 8636

www.lshtm.ac.uk

Observational / Interventions Research Ethics Committee

Mr Ilan Cerna-Turoff

LSHTM

4 August 2017

Dear Ilan

Study Title: Understanding how humanitarian crises effect violence against children on the individual, household and community level: A quantitative analysis of Haiti and the Democratic Republic of Congo

LSHTM Ethics Ref: 14413

Thank you for your application for the above research project which has now been considered by the Observational Committee via Chair's Action.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation, subject to the conditions specified below.

Conditions of the favourable opinion

Approval is dependent on local ethical approval having been received, where relevant.

Approved documents

The final list of documents reviewed and approved is as follows:

Document Type	File Name	Date	Version
Protocol / Proposal	Upgrading document_final_IlanCernaTuroff	13/07/2017	Final
Investigator CV	Ilan Salvador Cerna-Turoff_CV_11	19/07/2017	1

After ethical review

The Chief Investigator (CI) or delegate is responsible for informing the ethics committee of any subsequent changes to the application. These must be submitted to the committee for review using an Amendment form. Amendments must not be initiated before receipt of written favourable opinion from the committee.

The CI or delegate is also required to notify the ethics committee of any protocol violations and/or Suspected Unexpected Serious Adverse Reactions (SUSARs) which occur during the project by submitting a Serious Adverse Event form.

An annual report should be submitted to the committee using an Annual Report form on the anniversary of the approval of the study during the lifetime of the study.

At the end of the study, the CI or delegate must notify the committee using the End of Study form.

All aforementioned forms are available on the ethics online applications website and can only be submitted to the committee via the website at: http://leo.lshtm.ac.uk.

Further information is available at: www.lshtm.ac.uk/ethics.

Yours sincerely,

[redacted]

ro essor o n or er
Chair

ethics@lshtm.ac.uk
http://www.lshtm.ac.uk/ethics/

London School of Hygiene & Tropical Medicine
Keppel Street, London WC1E 7HT
United Kingdom
Switchboard: +44 (0)20 7636 8636

www.lshtm.ac.uk

Observational / Interventions Research Ethics Committee

Mr Ilan Cerna-Turoff
LSHTM

21 November 2018

Dear Mr Cerna-Turoff

Study Title: Understanding how humanitarian crises effect violence against children on the individual, household and community level: A quantitative analysis of Haiti and the Democratic Republic of Congo

LSHTM Ethics Ref: 14413 - 1

Thank you for your application for the above amendment to the existing ethically approved study and submitting revised documentation The amendment application has been considered by the Observational Committee via Chair's Action.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above amendment to research on the basis described in the application form, protocol and supporting documentation as revised, subject to the conditions specified below.

Conditions of the favourable opinion

Approval is dependent on local ethical approval for the amendment having been received, where relevant.

Approved documents

The final list of documents reviewed and approved is as follows:

Document Type	File Name	Date	Version
Other	ammendment_upgradingdoc_IlanCernaTuroff	12/11/2018	2

After ethical review

The Chief Investigator (CI) or delegate is responsible for informing the ethics committee of any subsequent changes to the application. These must be submitted to the committee for review using an Amendment form. Amendments must not be initiated before receipt of written favourable opinion from the committee.

The CI or delegate is also required to notify the ethics committee of any protocol violations and/or Suspected Unexpected Serious Adverse Reactions (SUSARs) which occur during the project by submitting a Serious Adverse Event form.

An annual report should be submitted to the committee using an Annual Report form on the anniversary of the approval of the study during the lifetime of the study.

At the end of the study, the CI or delegate must notify the committee using the End of Study form.

All aforementioned forms are available on the ethics online applications website and can only be submitted to the committee via the website at: http://leo.lshtm.ac.uk.

Further information is available at: www.lshtm.ac.uk/ethics.

Yours sincerely,

[redacted]

Professor John DH Porter
Chair

ethics@lshtm.ac.uk
http://www.lshtm.ac.uk/ethics/

Appendix B. Research paper 1 - supplementary materials

All citations and page numbers in Appendix B correspond to the typeset version of the chapter for ease of referencing.

S1 Table. PRISMA checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	Title page, p. 1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	Abstract, pp. 2-3
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	Introduction, pp. 3-6

Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	Introduction, pp. 6
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	Methods, Systematic literature review, p. 9; S2 Table
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	Methods, Systematic literature review, pp. 6-7; S9 Table
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	Methods, Systematic literature review, p. 8; S8 Table

Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	S3 Table
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	Methods, Systematic literature review, p. 7
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	Methods, Systematic literature review, p. 8
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	Methods, Data synthesis, pp. 9-10
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	Methods, Systematic literature review, p. 8-9
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	Methods, Data synthesis, pp. 9

Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	Methods, Data synthesis, pp. 9-10
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	Methods, Data synthesis, p. 10
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	Methods, Data synthesis, p. 10
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	Fig 1, p. 11
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Results, Study characteristics and quality, pp. 10-13; S4 Table

Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Table 2, pp. 14-16; S5 & S6 Tables
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Results, Combined violence outcomes, p. 17; Fig 2, p. 17
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	Results, Combined violence outcomes, p. 17; Fig 2, p. 17
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	-
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	Results, Subgroup analysis, p. 17-18;

			Table 3, pp. 17-18; S2-S13 Figs
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	Discussion, pp.18-21; Discussion, Implications, pp. 21-23
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	Discussion, Strengths and limitations, pp. 21
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	Discussion, p. 18-19; Discussion, Implications, pp. 21-23; Conclusions, p. 23
FUNDING			

Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	Financial Disclosure, cover page

Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009; 6(6): e1000097. doi: 10.1371/journal.pmed1000097.

S2 Table. Review protocol

Title: Violence against children and natural disasters: A systematic review and meta-analysis of quantitative evidence

Language: English

Publication period: database first publication date to May 16, 2018 (present)

Review Questions/Objectives:

- To identify the magnitude and direction of the association for physical, emotional and sexual violence against children after natural disasters
    - What is the magnitude and direction the association for physical, emotional and sexual violence against children after natural disasters?
    - What are the patterns by violence type, population and context?
    - How is exposure to natural disasters measured across studies?
    - What temporal elements of violence post-disaster have been identified?
- To map the evidence and examine the quality of the research
    - What is the current scope and risk of bias for the evidence?

Sources to be searched: The study team will search electronic databases, including: MEDLINE/PUBMED, EMBASE, PsychINFO, International Bibliography of Social Sciences, Global Health, SCOPUS, SciELO, Social Policy and Practice, Web of Science, CINAHL and regional databases (such as Africa-Wide Information, IndMed, IMEMR, LILACS, MedCarib, WPRIM). The search strategy will include strings related to: 1) children, 2) physical, sexual and emotional violence and 3) natural disasters. The child

and violence search strings were adapted from an on-going systematic review of risk and protective factors which, in turn, was based upon verified search strategies from other reviews. Additional terms for violence and bullying were constructed using two Cochrane review search strategies for similar concepts [59, 60]. The natural disaster terms were compiled from listing and testing possible natural disaster typologies. The search will be restricted to articles in English and children and adolescents under the age of 18. The searches will run for all articles, from the first record until the present.

Condition or domain to be studied: natural disasters, including rapid or slow onset disasters—tsunamis, volcanoes and other weather-related or geological phenomena—and violence against children

Participants/population:

Inclusion: children and adolescents under the age of 18

Exclusion: adults (18 years of age and older)

Intervention(s)/Exposure(s): The purpose of the systematic review is to map the evidence and to identify the magnitude and direction of the association and to identify reasons for changes in physical, emotional and sexual violence against children and natural disasters. The systematic review includes both longitudinal and cross-sectional study designs; however, the majority of the evidence is likely to be cross-sectional, given that natural disasters are unpredictable events. Much of the literature has lumped man-made and natural disasters together, with the assumption that they have a common effect of widespread social disruption on all forms of violence.

Comparator/control: The exact comparison group, as specified in the article, will be extracted. This could include: a group with no exposure to the natural disaster, pre-disaster measurements for exposed individuals or the underlying population, or no comparison group. If the same underlying population is sampled, the author's definition of the sampling population will be included in data extraction.

Types of studies to be included: The review will assess quantitative studies of natural disasters with an outcome measure of physical, sexual and/or emotional violence against children, aged 0-17. The included articles will describe original research which excludes opinion articles and policy reviews. The study team will include only peer reviewed publications.

Inclusion criteria

1. Natural disasters are the exposure/treatment
2. Physical, sexual, or emotional violence are an outcome measure of the study
3. Person experiencing violence is a child or adolescents under 18
    - Includes both self-reported violence by someone under 18 at the time of interview and violence reported by an adult respondent against someone under 18
    - Includes violence against children when it is committed by caregivers who are under 18
    - If age range includes people older than 18, include article only if it includes an age breakdown for those under 18
4. Original research in peer-reviewed journal articles
    - **Original research** is defined as a new study conducted or a unique analysis of primary or secondary data. It does not include literature reviews

5. All types of quantitative study designs

Exclusion criteria

1. Articles that have gang violence, female genital mutilation (FGM) or child labor/exploitation/trafficking/marriage as outcome measures
2. Articles that use neglect as an outcome measure
3. Editorials, policy reviews or general reports that do not introduce new evidence from a specific study
4. Conference abstracts or posters
5. Literature reviews
6. Articles focused on aggression reactions or mental health sequelae in potential perpetrators without mention of an explicit act of violence against a child
7. Articles that did not describe the magnitude or association between natural disasters and violence against children

Context: Global

Primary outcome: Physical, emotional and sexual violence are the primary outcomes of interest. Violence can be defined as a wide range of behaviours (i.e. verbal abuse, bullying). We utilized adapted UNICEF broad definitions of physical, emotional and sexual violence to define violence categories for data synthesis and will further extract violence definitions when specified. The definition of each violence category is:

- **Physical violence** is defined as "…all corporal punishment and all other forms of torture, cruel, inhuman or degrading treatment or punishment as well as

physical bullying and hazing by adults or by other children" (United Nations Children's Fund, [55], p. 4);

- **Emotional violence** is defined as "psychological maltreatment, mental abuse, verbal abuse and emotional abuse" (United Nations Children's Fund [55], p. 4); and
- **Sexual violence** is defined as "any sexual activities imposed by an adult on a child against which the child is entitled to protection under criminal law" or "…committed against a child by another child if the offender is significantly older than the victim or uses power, threat or other means of pressure" (United Nations Children's Fund [55], p. 4).

These categories of violence include violence from adults or peers and violence that occurs within and outside of households. It includes violence against married adolescents under the age of 18.

Secondary outcomes: None

Data extraction: Titles and/or abstracts retrieved using the search strategy will be screened independently by the primary and secondary author for inclusion. The first round of screening will include articles that: 1) have some form of physical, emotional, sexual or related form of violence as the outcome of interest, 2) focus on children, 17 years and younger, as the recipients of the violence and 3) describe a natural disaster exposure. The two review authors will discuss articles identified in the title and abstract review and if necessary, consult with a third reviewer if discrepancies cannot be resolved.

The full texts of the selected abstracts will then be screened independently. The primary author will create a standardised, electronic data extraction form to synthesize the evidence. The extracted information will include information on: pre-disaster setting characteristics; study population; the type of disaster; experience of displacement after disaster; respondent type; violence category (physical, emotional or sexual); definition used for measurement of violence; prevalence/rate/risk/odds (adjusted and unadjusted); and analysis methodology. The data extraction sheet will be pilot tested with a series of relevant articles to ensure that all pertinent information is included. Data will be extracted in duplicate and selected articles will be sorted by overarching and specific study definitions of violence. Any disagreement between the two authors during data extraction will be resolved through discussion with a third reviewer if necessary. Missing data will be solicited from study authors if appropriate.

Risk of bias (quality) assessment: As articles are being selected for inclusion, the two reviewing authors will each separately assess the dimensions for the possible risk of bias. The primary author will adapt questions from a checklist for the assessment of bias in quantitative studies to explore study quality and embed it in the data extraction form. Each aspect for the risk of bias will be categorized as per the recommendations of the Cochrane Handbook for Systematic Reviews of Interventions. Discrepancies in scoring will be discussed between the two reviewing authors. Any possible sources of bias will be checked by the third reviewer.

Strategy for data synthesis: The primary author will provide a separate narrative synthesis of findings, structured around the disaster type, study population, outcome measures and time/location of measurement and analysis methods. Limitations and biases will also be treated in a distinct section. Meta-analysis of the results will also be conducted

for the whole dataset and subdivided into analyses by violence type, unadjusted and adjusted outcome measures, studies without lifetime experiences of violence and studies that compared pre- and post- measures. When appropriate, pooled odds ratios for dichotomous outcomes and mean differences for continuous outcomes with confidence intervals will be provided. A final discussion section will discuss possible future areas of development for studying natural disasters and violence against children. It will additionally examine gaps in data collection and the current state of the quantitative evidence.

Analysis of subgroups or subsets: Results from similar subgroups will be compared when possible and if present. The analysis will likewise examine subsets by violence type, statistical analysis methods, and study designs.

Type and method of review:

Type

- Epidemiologic
- Methodology
- Systematic Review

Area

- Child health
- Violence and abuse

Dissemination plans: We intend to submit this article to a leading journal in the field. We intend to present the results in conferences and disseminate via professional networks of researchers and practitioners.

Keywords: Child; child abuse; violence; natural disasters; disasters; emergencies; meta-analysis; systematic review

S3 Table. **Medline search strategy**

Search Number	Search	Results
Population String		
#1	child*.ab,ti.	1214705
#2	minor*.ab,ti.	259764
#3	schoolchild*.ab,ti.	12509
#4	infan*.ab,ti.	391717
#5	adolescen*.ab,ti.	230535
#6	newborn*.ab,ti.	147013
#7	preschool*.ab,ti.	24135
#8	pre-school*.ab,ti.	4399
#9	kindergarten*.ab,ti.	5379
#10	underage.ab,ti.	949
#11	youth.ab,ti.	50522
#12	youths.ab,ti.	9935
#13	baby.ab,ti.	33627
#14	babies.ab,ti.	33149
#15	prepubescen*.ab,ti.	912
#16	pubescen*.ab,ti.	1982
#17	schoolage.ab,ti.	40
#18	school-age.ab,ti.	11454
#19	boy*.ab,ti.	137310
#20	girl*.ab,ti.	131640

#21	offspring.ab,ti.	61110
#22	pediatric*.ab,ti.	240605
#23	paediatric*.ab,ti.	53332
#24	juvenile*.ab,ti.	71739
#25	toddler*.ab,ti.	8729
#26	“nursery school*”.ab,ti.	1024
#27	“elementary school*”.ab,ti.	8413
#28	“high school*”.ab,ti.	26747
#29	highschool*.ab,ti.	40
#30	“primary school*”.ab,ti.	10300
#31	“secondary school*”.ab,ti.	8660
#32	daycare.ab,ti.	1125
#33	teen.ab,ti.	4672
#34	teens.ab,ti.	5537
#35	teenage*.ab,ti.	18827
#36	“child” [Mesh]	1934614
#37	“adolescent” [Mesh]	1888759
#38	“infant” [Mesh]	1111323
#39	**or/1-38**	4091681
Physical/emotional/ sexual violence string		
#40	(physical adj2 violen*).ab,ti.	2334
#41	(sexual adj2 violen*).ab,ti.	3131

#42	(emotional adj2 violen*).ab,ti.	271
#43	(psychological adj2 violen*).ab,ti.	550
#44	(mental adj2 violen*).ab,ti.	472
#45	(physical adj2 abuse).ab,ti.	5168
#46	(sexual adj2 abuse).ab,ti.	11391
#47	(emotional adj2 abuse).ab,ti.	1741
#48	(mental adj2 abuse).ab,ti.	1127
#49	(psychological adj2 abuse).ab,ti.	786
#50	(verbal adj2 abuse).ab,ti.	739
#51	“child abuse”.ab,ti.	7805
#52	(physical adj2 assault*).ab,ti.	4034
#53	(sexual adj2 assault*).ab,ti.	932
#54	“physical attack*”.ab,ti.	146
#55	(severe adj2 punishment).ab,ti.	82
#56	(harsh adj2 punishment).ab,ti.	89
#57	“corporal punishment”.ab,ti.	451
#58	“corporeal punishment”.ab,ti.	4
#59	(severe adj2 discipline).ab,ti.	11
#60	(harsh adj2 discipline).ab,ti.	157
#61	“harsh parenting”.ab,ti.	233
#62	harass*ab,ti.	2918
#63	incest.ab,ti.	1276
#64	maltreat*.ab,ti.	5885
#65	“sexual violation*”.ab,ti.	36
#66	“forced sex”.ab,ti.	310

#67	“coerced sex”.ab,ti.	38
#68	rape.ab,ti.	6536
#69	mistreat*.ab,ti.	1491
#70	molest*.ab,ti.	1155
#71	defile*.ab,ti.	58
#72	(adverse adj childhood adj experience*).ab,ti.	901
#73	“ACE”.ab,ti.	30961
#74	“violence against children”.ab,ti.	268
#75	(abuse* adj2 spous*).ab,ti.	356
#76	(abuse* adj2 partner*).ab,ti.	615
#77	((wife or wives) adj2 abuse*).ab,ti.	153
#78	((wife or wives) adj2 batter*).ab,ti.	114
#79	(partner* adj2 violen*).ab,ti.	5774
#80	(spous* adj2 violen*).ab,ti.	145
#81	“dating violen*”.ab,ti.	687
#82	“bully*”.ab,ti.	3985
#83	“bullie*”.ab,ti.	1341
#84	((antisocial or agonis*) adj2 behavi*).ab,ti.	4733
#85	“intimidat*”.ab,ti.	1117
#86	“aggression*”.ab,ti.	25105
#87	(peer* adj2 violen*).ab,ti.	161
#88	(peer* adj2 victim*).ab,ti.	817
#89	“juvenile delinquency” [Mesh]	8304
#90	“bullying” [Mesh]	4950
#91	“physical abuse” [Mesh]	4642

#92	“domestic violence” [Mesh]	8732
#93	“intimate partner violence” [Mesh]	5528
#94	“spouse abuse” [Mesh]	7203
#95	“battered women” [Mesh]	2840
#96	“rape" [Mesh]	9944
#97	“child abuse” [Mesh]	30909
#98	**or/40-97**	140321
Natural disasters string		
#99	(Natural adj2 disaster*).ti,ab.	3133
#100	(humanitarian adj2 (cris* OR emergenc* OR disaster*).ti,ab.	603
#101	(complex adj2 emergenc*).ti,ab.	542
#102	(displace$ adj2 (force$ or population or human or internal$)).ti,ab.	2962
#103	avalanche*.ti,ab.	2443
#104	earthquake*.ti,ab.	6902
#105	temblor*.ti,ab.	17
#106	volcano*.ti,ab.	1896
#107	"volcanic eruption*".ti,ab.	477
#108	supervolcano*.ti,ab.	10
#109	flood*.ti,ab.	13106
#110	landslide*.ti,ab.	445
#111	mudslide*.ti,ab.	35

#112	sinkhole*.ti,ab.	103
#113	sink-hole*.ti,ab.	11
#114	"limnic eruption*".ti,ab.	4
#115	"tidal wave*".ti,ab.	125
#116	tsunami*.ti,ab.	2075
#117	cyclone*.ti,ab.	1244
#118	"cyclonic storm*".ti,ab.	12
#119	typhoon*.ti,ab.	482
#120	hurricane*.ti,ab.	2898
#121	"tropical storm*".ti,ab.	147
#122	tornado*.ti,ab.	591
#123	storm*.ti,ab.	10979
#124	thunderstorm*.ti,ab.	320
#125	rainstorm*.ti,ab.	162
#126	hailstorm*.ti,ab.	24
#127	"winter storm*".ti,ab.	80
#128	snowstorm*.ti,ab.	121
#129	blizzard*.ti,ab.	190
#130	wildfire*.ti,ab.	1328
#131	bushfire*.ti,ab.	217
#132	"heat wave*".ti,ab.	1128
#133	heatwave*.ti,ab.	309
#134	drought*.ti,ab.	15516
#135	famine*.ti,ab.	2061
#136	"disasters" [MeSH]	22490

#137	**or/99-136**	76963
#138	39 and 98 and 137	283
#139	limit 138 to (English language and human)	235
#140	139 not ((case report or editorial).ti,ab. or editorial.ptyp. or letter.ptyp. or newspaper article.ptyp.)	235

S4 Table. Descriptive analysis of included studies

1. **Data source and country:** Becker-Blease et al. [73], United States

***N*:** 1008 caregivers and 1016 ten to seventeen year olds

Disaster type: Any form of disaster

Measure exposure: Lifetime exposure to "very bad" disasters, including man-made disasters

Measure violence: Lifetime frequency of sexual; maltreatment; witnessing domestic violence/intimate partner violence; other major violence; any victimization events

Perpetrator types: Not specified

Respondent types: Parent/caregiver of children two to nine years old in randomly selected households; a random selection of parent/caregiver or child between ten to seventeen years old

Factors used in adjustment: Age of child; race; number of children in household; stratified by age group

2. **Data source and country:** Biswas et al. [81], Bangladesh

***N*:** 638 mothers

Disaster type: Flood

Measure exposure: Living in the most flood-affected areas from late July to early September 2007

Measure violence: Past week binary of combined physical and emotional – sampled mid-September to October

Perpetrator types: Fathers; mothers

Respondent types: Randomly selected married women of reproductive age with at least one child in household

Factors used in adjustment: Age of respondent; religion; housing material; education; occupation; income; husband's occupation; husband's income; micro-credit loan; economic survival method during flood; wife abused during flood

3. **Data source and country:** Catani et al. [80], Sri Lanka

***N*:** 296 nine to fifteen year olds

Disaster type: Tsunami

Measure exposure: five-question tsunami severity checklist – data collection date not reported

Measure violence: Lifetime frequency of family violence events – combined physical, emotional, sexual, and witnessing domestic violence/intimate partner violence

Perpetrator types: Families; household members

Respondent types: Randomly selected Tamil schoolchild

Factors used in adjustment: Age of child; gender; economic status; father alive; mother alive; father drinks alcohol; previous exposure to war

4. **Data source and country:** Curtis et al. [74], United States

***N*:** *Three months*: 185 before and 259 after Hurricane Hugo; 9895 before and 10,803 after Loma Prieta Earthquake; 610 before and 515 after Hurricane Andrew.

Six months: 485 before and 599 after Hurricane Hugo; 20,703 before and 22,565 after Loma Prieta Earthquake; 1177 before and 959 after Hurricane Andrew.

Eleven months: 1023 before and 1184 after Hurricane Hugo; 39,419 before and 40,537 after Loma Prieta Earthquake; 2141 before and 1788 after Hurricane Andrew.

Disaster type: Earthquake; hurricane

Measure exposure: Catastrophic damage to the entire parish or county and presidential disaster declaration for the county

Measure violence: Reported and confirmed physical; emotional; sexual; combined physical and sexual; combined physical, emotional, and sexual cases three months, six months, and eleven months pre/post disaster

Perpetrator types: Not specified

Respondent types: Administrative review of child protective service cases

Factors used in adjustment: Seasonal variation; national annual increases

5. **Data source and country:** Keenan et al. [75], United States

***N*:** 245 cases

Disaster type: Hurricane; flood

Measure exposure: Severely affected counties with any drowning-related deaths; ≥ $500,000 of state/federal funds allocated for infrastructure rebuilding; and/or ≥ 100 home buyouts

Measure violence: Inflicted traumatic brain injury ~ 12 months before the disaster, during the first 6 months after disaster, and the subsequent 6 to 21.5 months after the disaster

Perpetrator types: Not specified

Respondent types: Retrospective and prospective chart review of fatal or severe brain injury admissions to pediatric intensive care units and retrospective fatality chart review from the Office of the Chief Medical Examiner

Factors used in adjustment: Age of child; Race/ethnicity

6. **Data source and country:** Kelley et al. [76], United States

***N*:** 279 cases and 96 controls

Disaster type: Hurricane

Measure exposure: Hurricane Related Traumatic Experiences (HURTE) scale – direct exposure defined by binary responses to objective or verifiable life-threatening events or one perceived threat question

Measure violence: No specified timeframe for frequencies of combined corporal punishment and yelling – sampled three to seven months after disaster

Perpetrator types: Mothers

Respondent types: Purposeful selection of mothers of schoolchildren

Factors used in adjustment: None

7. **Data source and country:** Madkour et al. [77], United States

***N*:** 1637 twelve to seventeen year olds in 2005; 2018 twelve to seventeen year olds in 2007

Disaster type: Hurricane

Measure exposure: All people in region in August 2005

Measure violence: Last 12 months binary of physical dating violence; lifetime binary of sexual violence – sampled August 2004 to August 2005 and spring 2006 to spring 2007

Perpetrator types: Boyfriend; girlfriend; not specified

Respondent types: Randomly selected public high school students

Factors used in adjustment: Age of child; race/ethnicity; gender

8. **Data source and country:** Sloand et al. [82], Haiti

***N*:** 78 twelve to seventeen year old girls

Disaster type: Earthquake

Measure exposure: None provided

Measure violence: No specified timeframe and question structure for physical; sexual; combined physical and sexual; combined physical, emotional, and sexual – sampled 12 to 36 months after disaster

Perpetrator types: Boyfriend; ex-boyfriend; other partners; family members; non-family members; authority figures; another person

Respondent types: Purposeful selection of internally displaced adolescent girls who came to local hospitals or clinics

Factors used in adjustment: None – sample of girls only

9. **Data source and country:** Sriskandarajah et al. [63], Sri Lanka

***N*:** 359 seven to eleven year olds; 108 mothers; 80 fathers

Disaster type: Tsunami

Measure exposure: 5-question tsunami severity checklist

Measure violence: Lifetime frequency of physical; emotional; sexual; combined physical, sexual, neglect, and witnessing domestic violence/intimate partner violence – sampled in 72 months after disaster

Perpetrator types: Fathers; mothers

Respondent types: Randomly selected Tamil schoolchildren and both caregivers/parents

Factors used in adjustment: None

10. **Data source and country:** Temple et al. [78], United States

***N*:** 464 fourteen to seventeen year old girls; 584 fourteen to seventeen year old boys

Disaster type: Hurricane; flood

Measure exposure: Not being evacuated from affected island in September 2008

Measure violence: Last 12-month binary of physical dating violence; lifetime binary of sexual dating violence – sampled March 2009

Perpetrator types: Boyfriend; girlfriend

Respondent types: Purposefully selected low-income public high school students

Factors used in adjustment: Age of child; ethnicity; stratified by gender

11. **Data source and country:** Terranova et al. [79], United States

***N*:** 96 cases and 96 controls

Disaster type: Hurricane

Measure exposure: Living within 35 miles of the eye of the storm in September 2005

Measure violence: No specified timeframe for frequency of relational bullying victimization (emotional); overt bullying victimization (physical) – sampled May and November 2005 for cases and spring 2004 and fall 2004 for controls

Perpetrator types: Peers

Respondent types: Purposefully selected fifth grade students from a rural, economically depressed region and random selection of controls

Factors used in adjustment: Gender

S5 Table. Risk of bias results for cross-sectional and cohort studies

Author	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Quality score
Becker-Blease et al. [73]	Y	Y	Y	Y	N	N	N	N	Y	N	Y	N	N/A	N	6
Biwas et al. [81]	Y	Y	Not reported	Y	Y	Y	Y	N	N	N	Y	N	N/A	Y	8
Catani et al. [80]	Y	Y	Not reported	Y	N	N	Not reported	Y	Y	N	Y	N	N/A	N	6
Curtis et al. [74]	Y	Y	N/A	Y	N	Y	Y	N	N	N	Y	N	N/A	Y	7
Keenan et al. [75]	Y	Y	N/A	Y	Y	Y	Y	N	Y	N	Y	Not reported	N/A	Y	9

Madkour et al. [77]	Y	Y	Y	Y	Y	N	N	N	N	N	Y	N	N/A	Y	7
Sloand et al. [82]	Y	Y	N	N	N	N	N	N	N	N	Y	N	N/A	N	3
Sriskandarajah et al. [63]	Y	Y	Y	Y	N	N	N	Y	Y	N	Y	N	N/A	N	7
Temple et al. [78]	Y	Y	Y	Not reported	N	N	Y	N	N	N	Y	N	N/A	Y	6

Y = Yes, N = No, and N/A = Not Applicable. 1. Clear research question; 2. Clear study population; 3. Participation rate of greater than or equal to 50%; 4. Recruited from the same population, timeframe, and consistent inclusion/exclusion; 5. Sample size justified, power description, or variance and effect estimation; 6. Exposure before outcome; 7. Timeframe under a year; 8 Varying levels of exposure measured; 9. Clear and consistent exposure; 10. Exposure assessed more than once over time; 11. Clear and consistent outcome; 12. Assessors blinded; 13. Loss to follow up less than or equal to 20%; 14. Key confounders adjusted.

S6 Table. Risk of bias results for case-control studies

Author	1	2	3	4	5	6	7	8	9	10	11	12	Quality score
Kelley et al. [76]	Y	Y	N	N	Y	Y	N	Y	N	Y	N/A	N	6
Terranova et al. [79]	Y	Y	N	N	N	Y	Y	Y	Y	Y	N/A	Y	8

Y = Yes, N = No, and N/A = Not Applicable. 1. Clear research question; 2. Clear study population; 3. Sample size justified; 4. Same population and timeframe; 5. Consistent inclusion/exclusion; 6. Cases different from controls; 7. (if less than 100 cases or controls): random selection; 8. Concurrent controls; 9. Exposure before outcome; 10. Clear and consistent exposure; 11. Assessors blinded; 12. Key confounders adjusted or (if matching): proper statistics.

S7 Table. Data used in R for meta-analysis

Excel spreadsheets containing the extracted and reconciled data used for the analyses is available online at: https://doi.org/10.1371/journal.pone.0217719.s007. This file includes individual point estimates and standard errors extracted from each study, divided by categorical and continuous outcomes. In addition, the following information is included for each estimate: (i) the country where the disaster occurred; (ii) type of disaster; (iii) violence type; (iv) perpetrator; (v) age of the child; (vi) respondent; (vii) sample size; (viii) data collection method; (ix) date/timeframe for the disaster measure; (x) date/timeframe for the violence measure; (xi) study design; and (xii) additional details relevant to the studies.

S8 Table. **Data repositories searched**

	Name
1	Medline
2	PsychINFO
3	Global Health
4	Social Policy and Practice
5	Scopus
6	Cumulative Index to Nursing & Allied Health Literature (CINAHL) Plus
7	Africa-Wide Information
8	Web of Science
9	International Bibliography of Social Sciences (IBSS)
10	Index Medicus for the Eastern Mediterranean Region (IMEMR)
11	Western Pacific Region Index Medicus (WPRIM)
12	Latin American and Caribbean Index Medicus (LILACS)
13	MedCarib
14	Indexing of Indian Medical Journals (IndMED)
15	China Academic Literature Database (CNKI English)

S9 Table. **Inclusion and exclusion criteria**

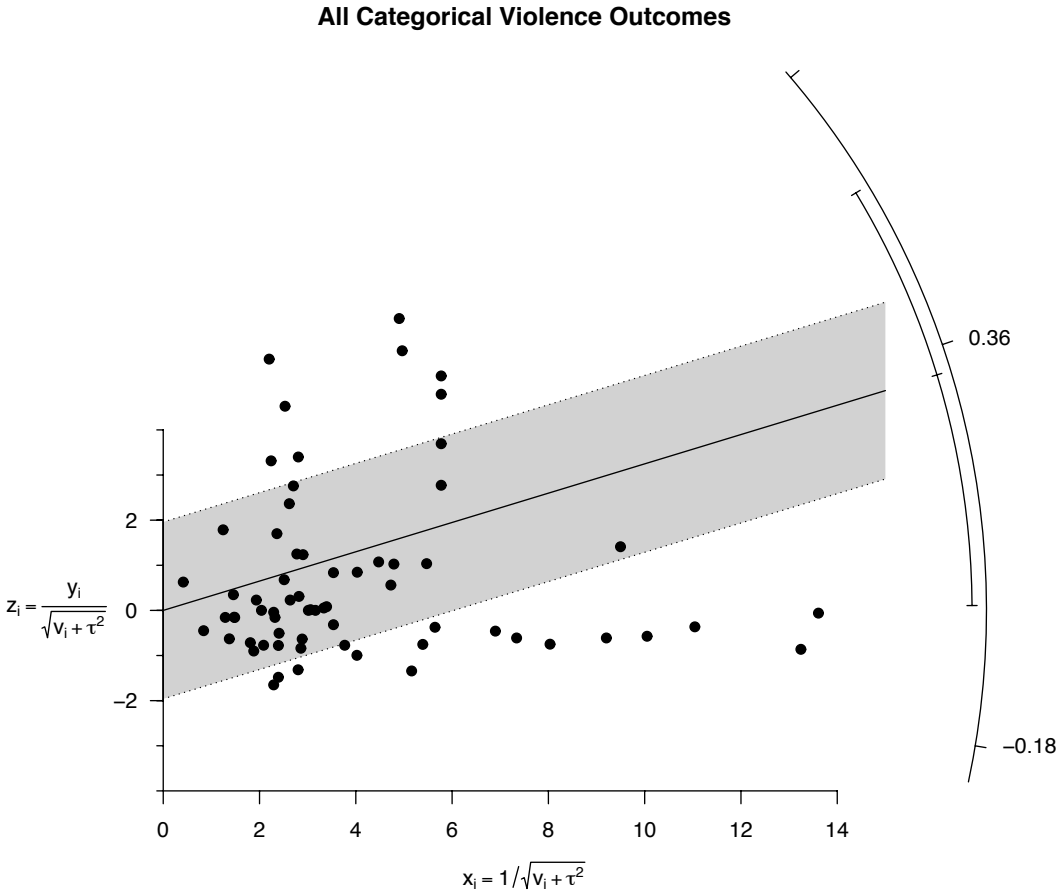
Inclusion criteria

1. Natural disasters are the exposure/treatment
2. A broad range of violence, including physical, emotional, and sexual violence, bullying, maltreatment, interpersonal violence, or witnessing domestic violence or intimate partner violence, is the outcome measure of the study
3. Person experiencing violence is a child or adolescents under 18
4. Original research published in peer-reviewed journal articles
5. All types of quantitative study design

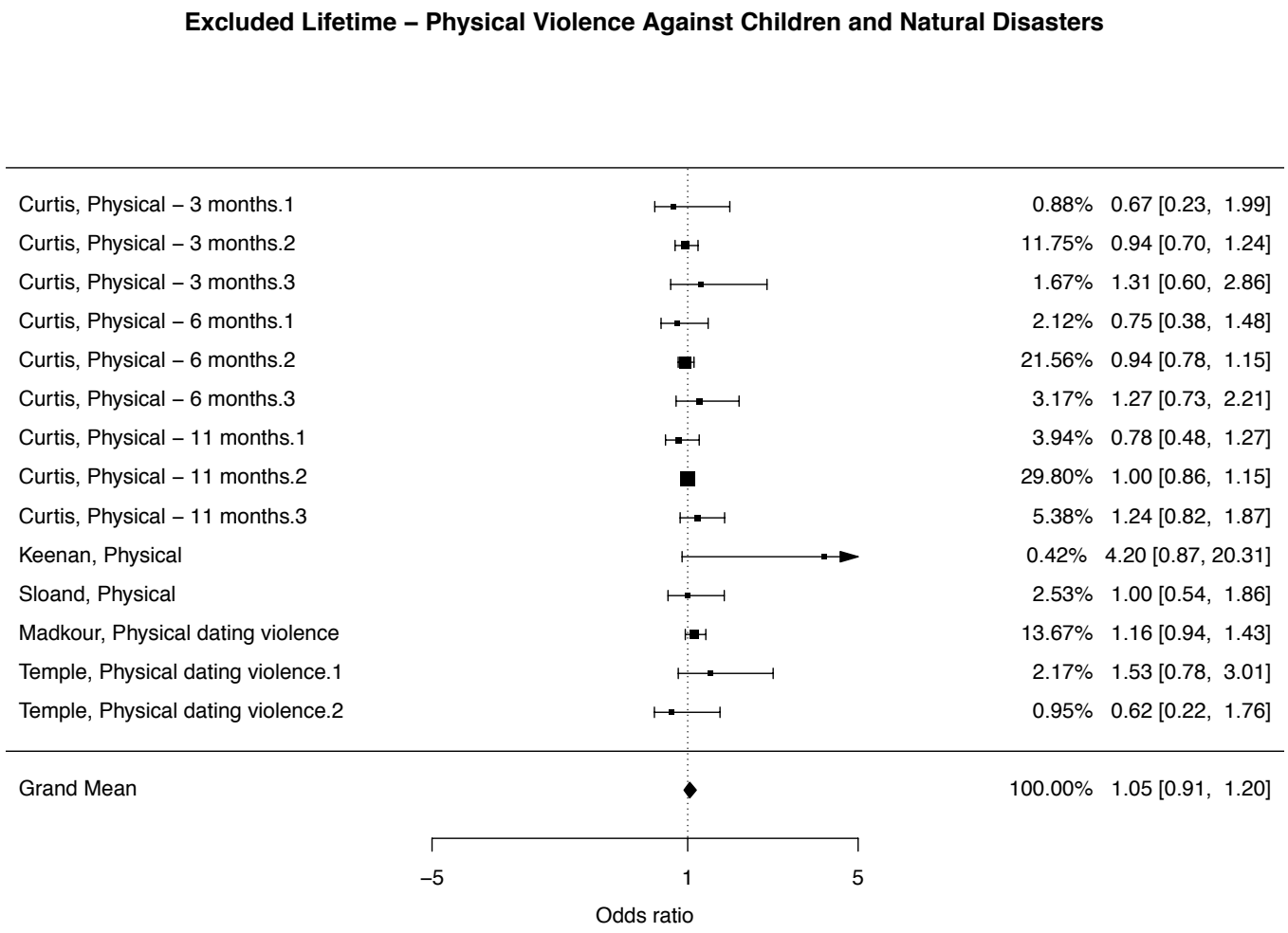
Exclusion criteria

8. Articles that have gang violence, female genital mutilation (FGM) or child labor/exploitation/trafficking/marriage as outcome measures
9. Articles that use neglect as an outcome measure
10. Editorials, policy reviews or general reports that do not introduce new evidence from a specific study
11. Conference abstracts or posters
12. Literature reviews
13. Articles focused on aggression reactions or mental health sequelae in potential perpetrators without mention of an explicit act of violence against a child
14. Articles that did not define a change in magnitude or association between natural disasters and violence against children

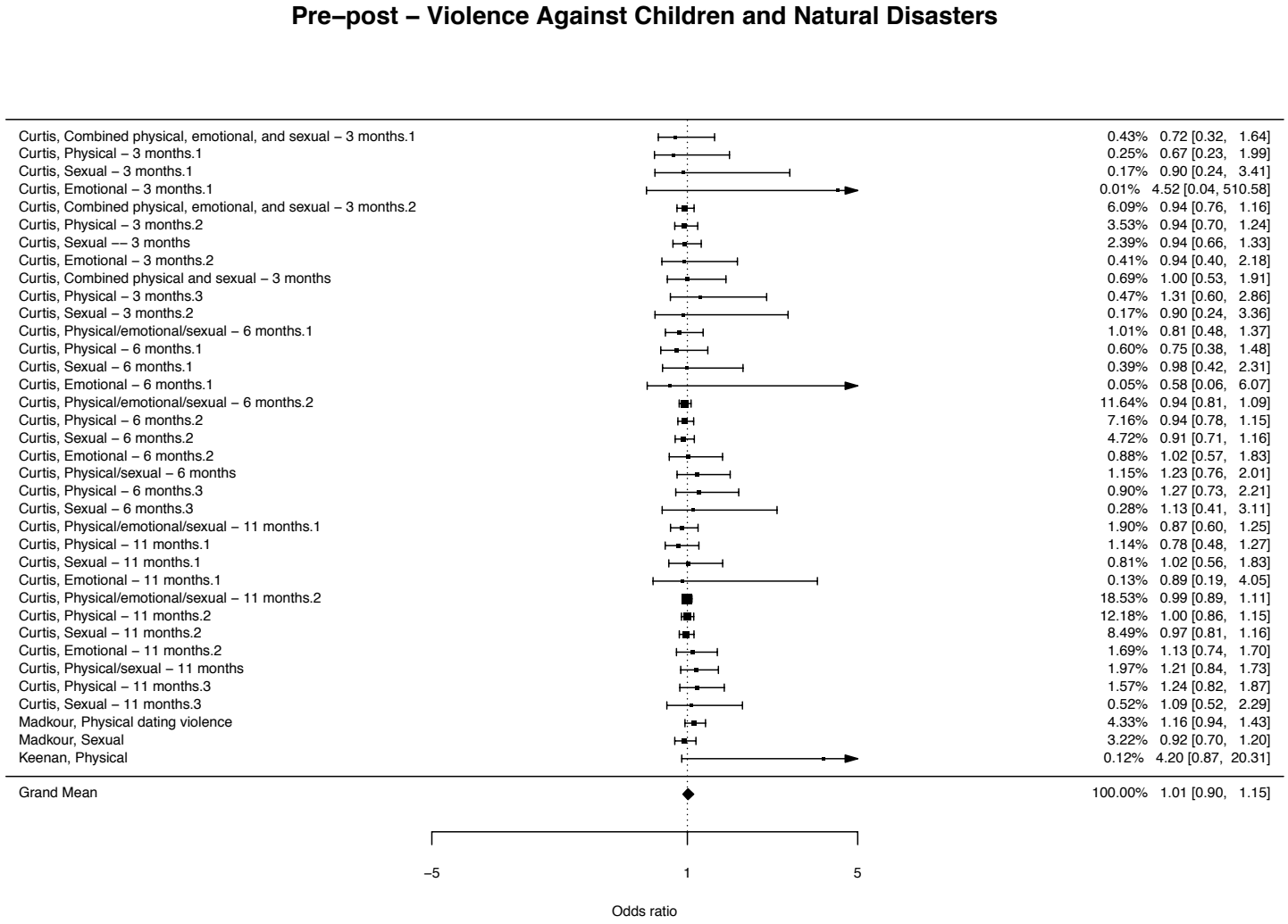
S1 Figure. All categorical violence outcomes radial plot



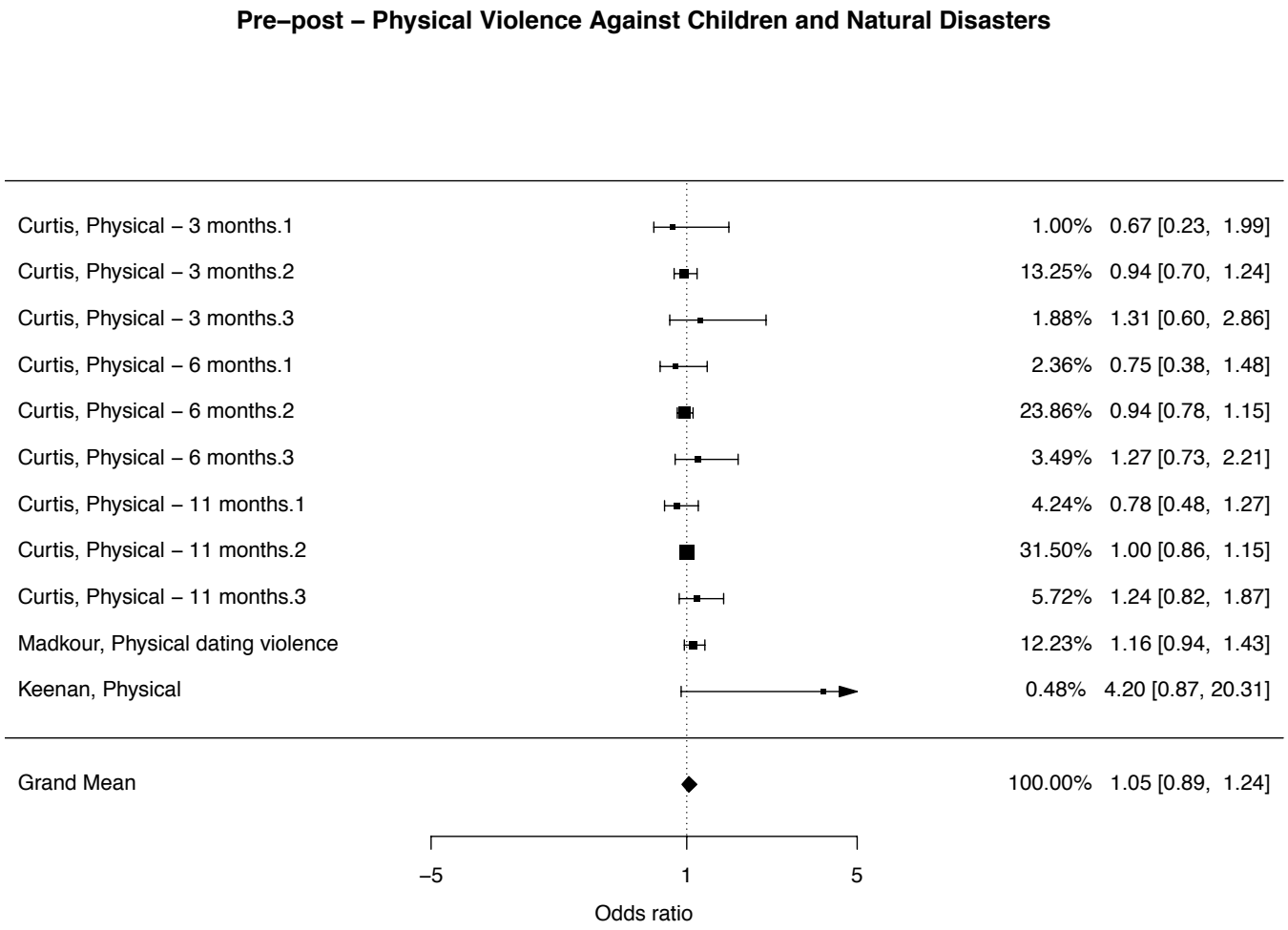
S2 Figure. Physical violence without lifetime measures forest plot



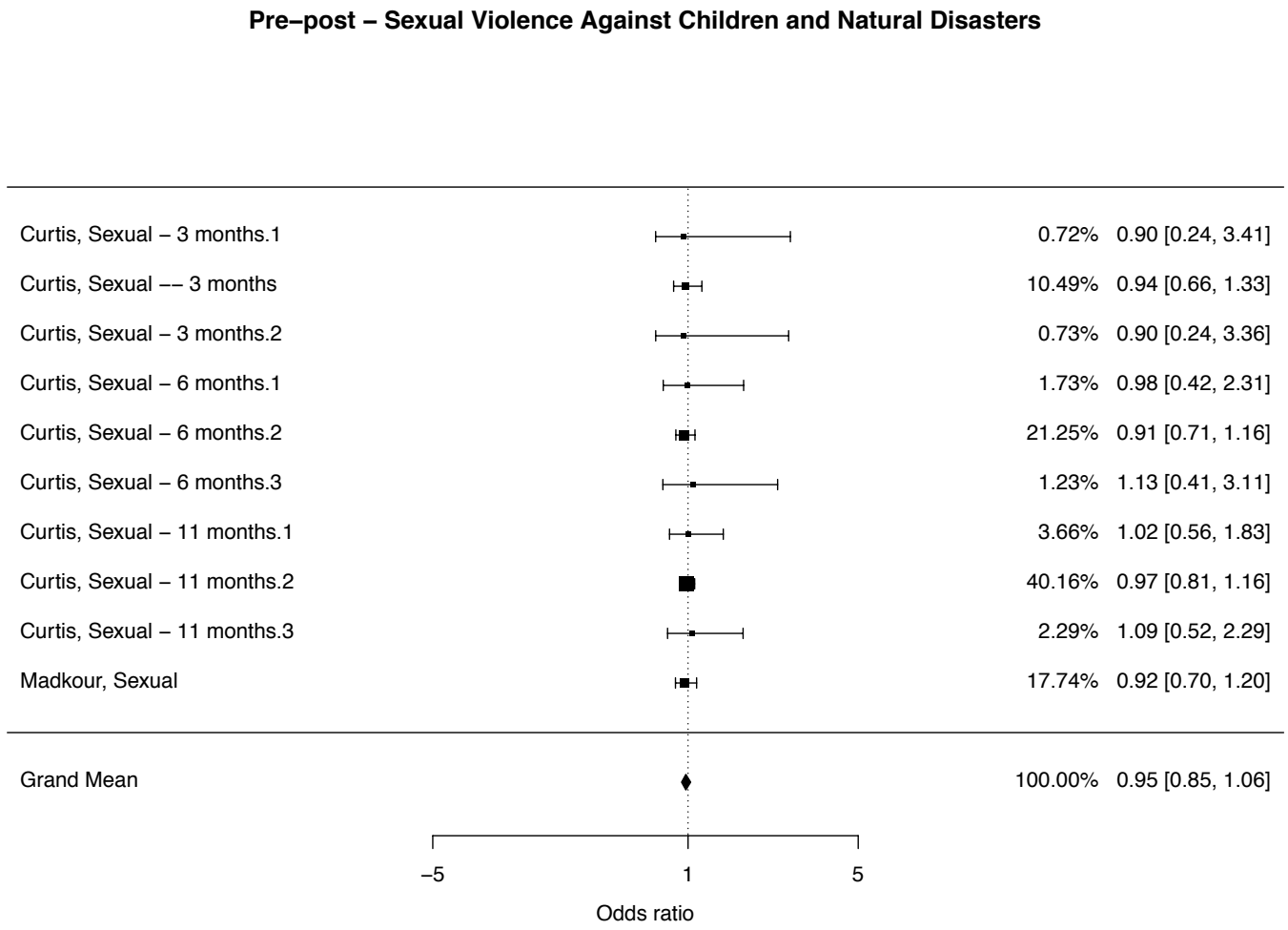
S3 Figure. All violence outcomes with pre-post design forest plot



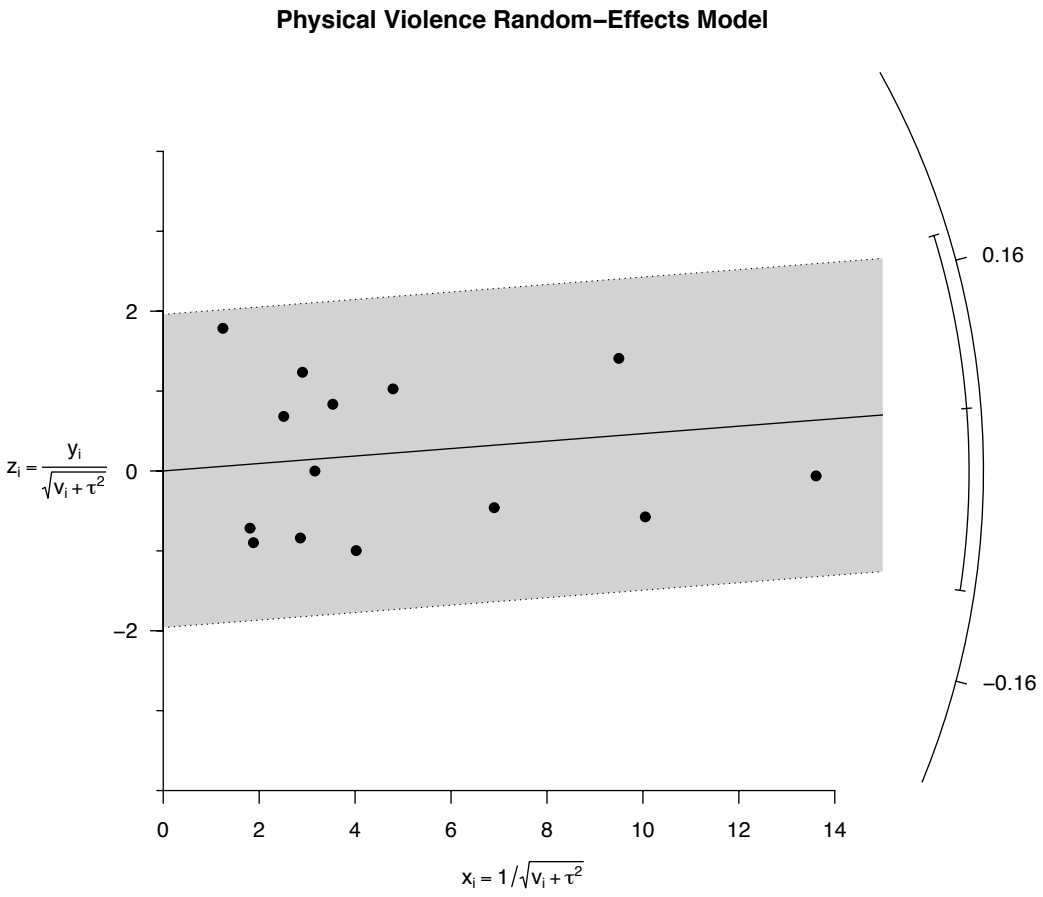
S4 Figure. Physical violence with pre-post design forest plot



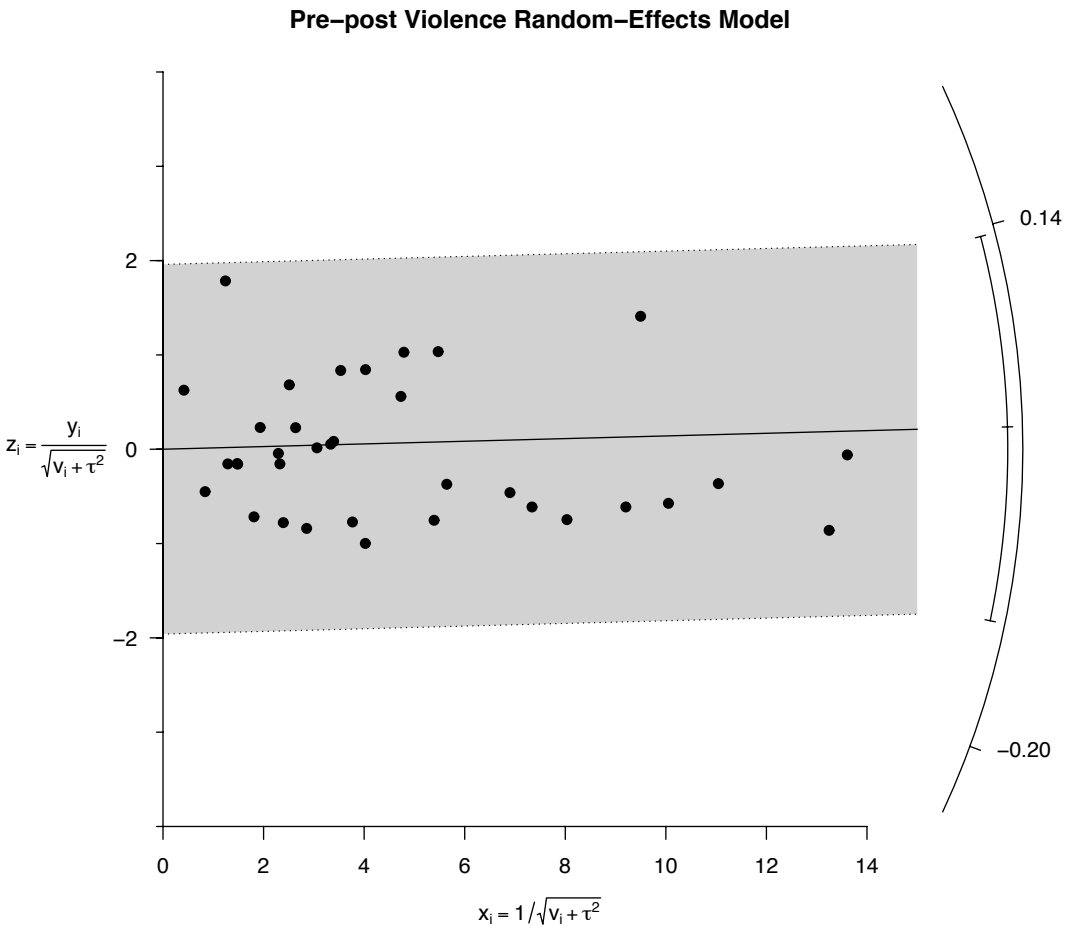
S5 Figure. Sexual violence with pre-post design forest plot



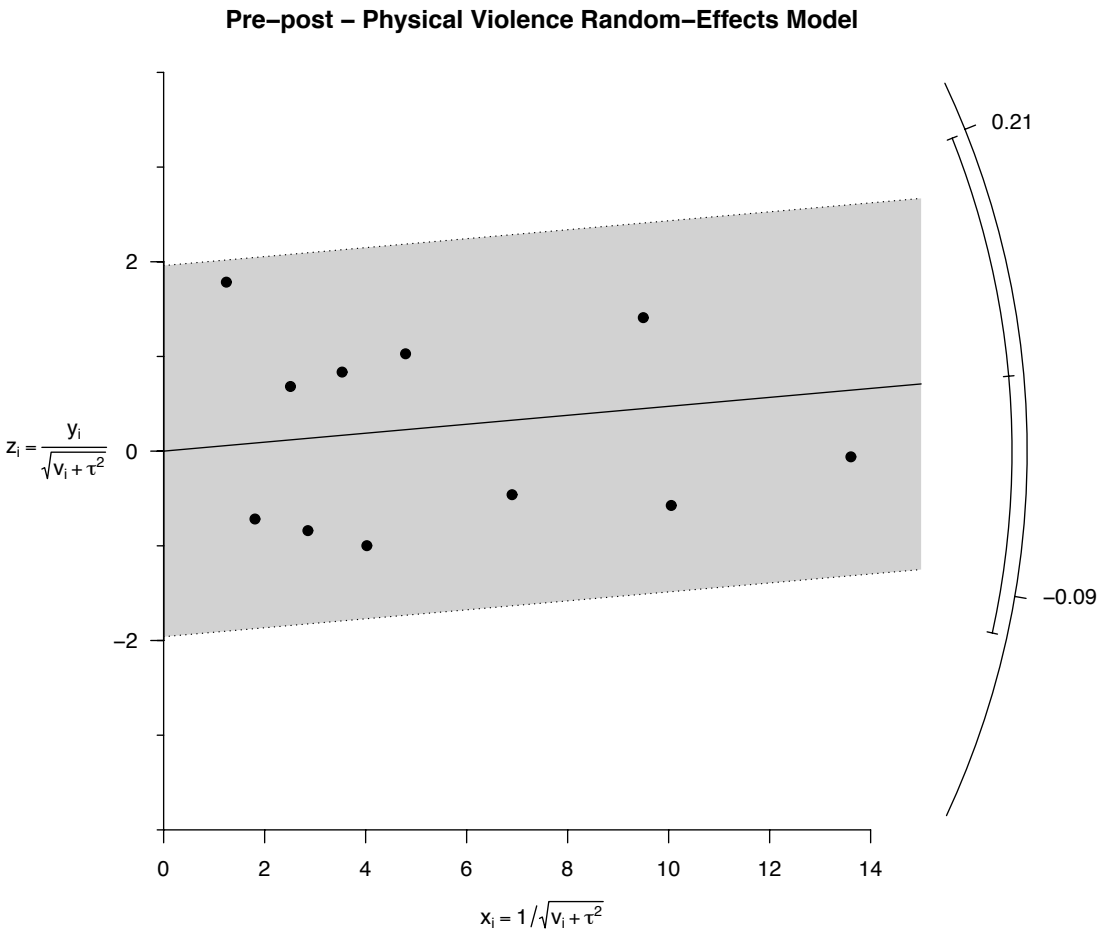
S6 Figure. Physical violence without lifetime measures radial plot



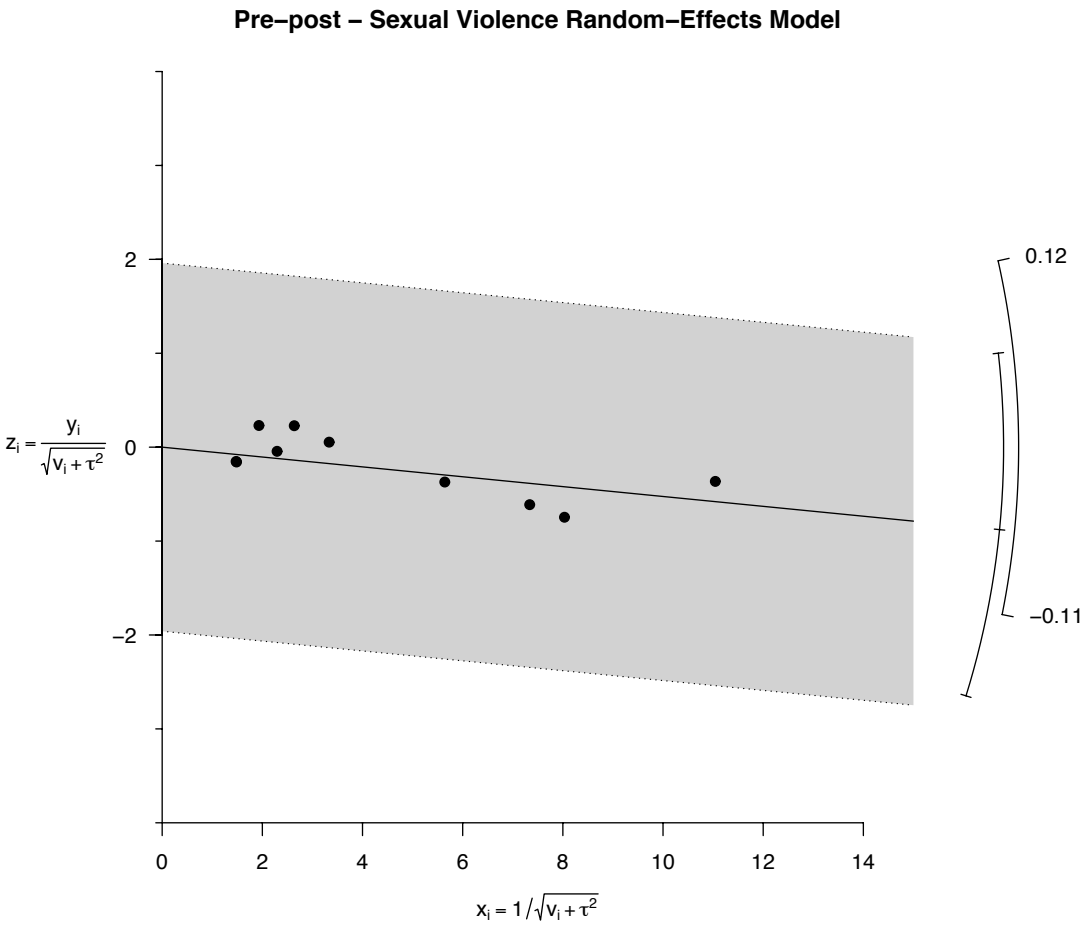
S7 Figure. All violence outcomes with pre-post design radial plot



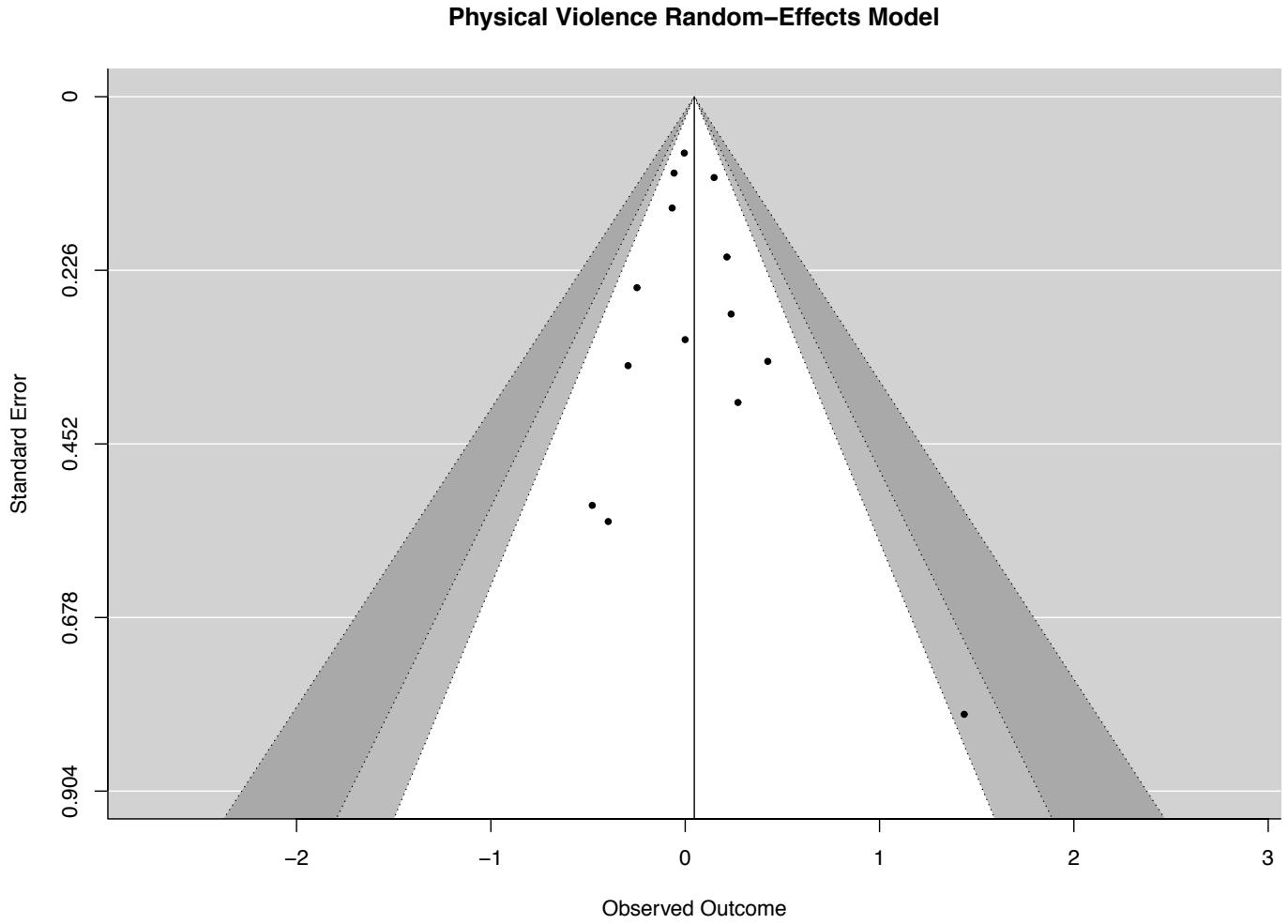
S8 Figure. Physical violence with pre-post design radial plot



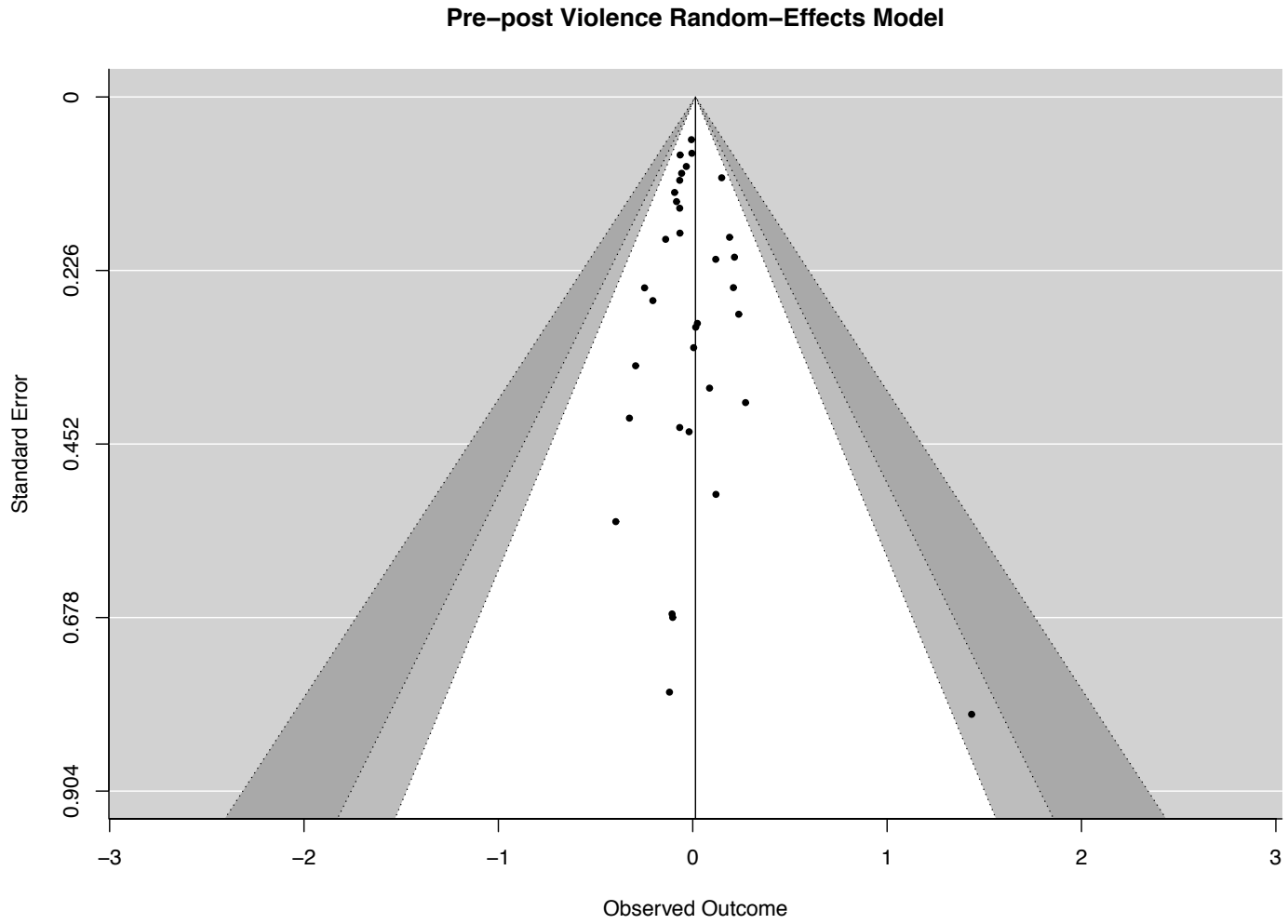
S9 Figure. Sexual violence with pre-post design radial plot



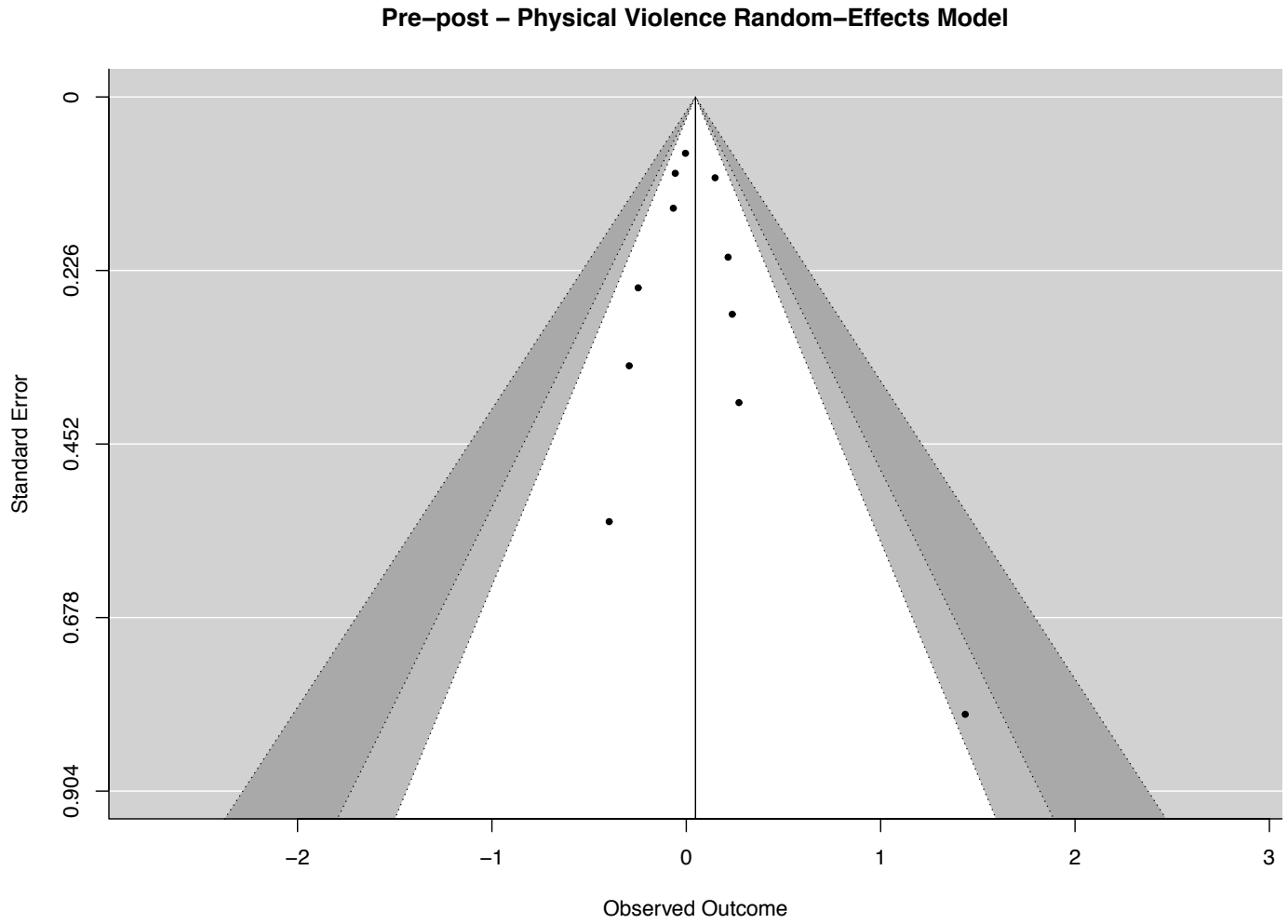
S10 Figure. Physical violence without lifetime measures funnel plot



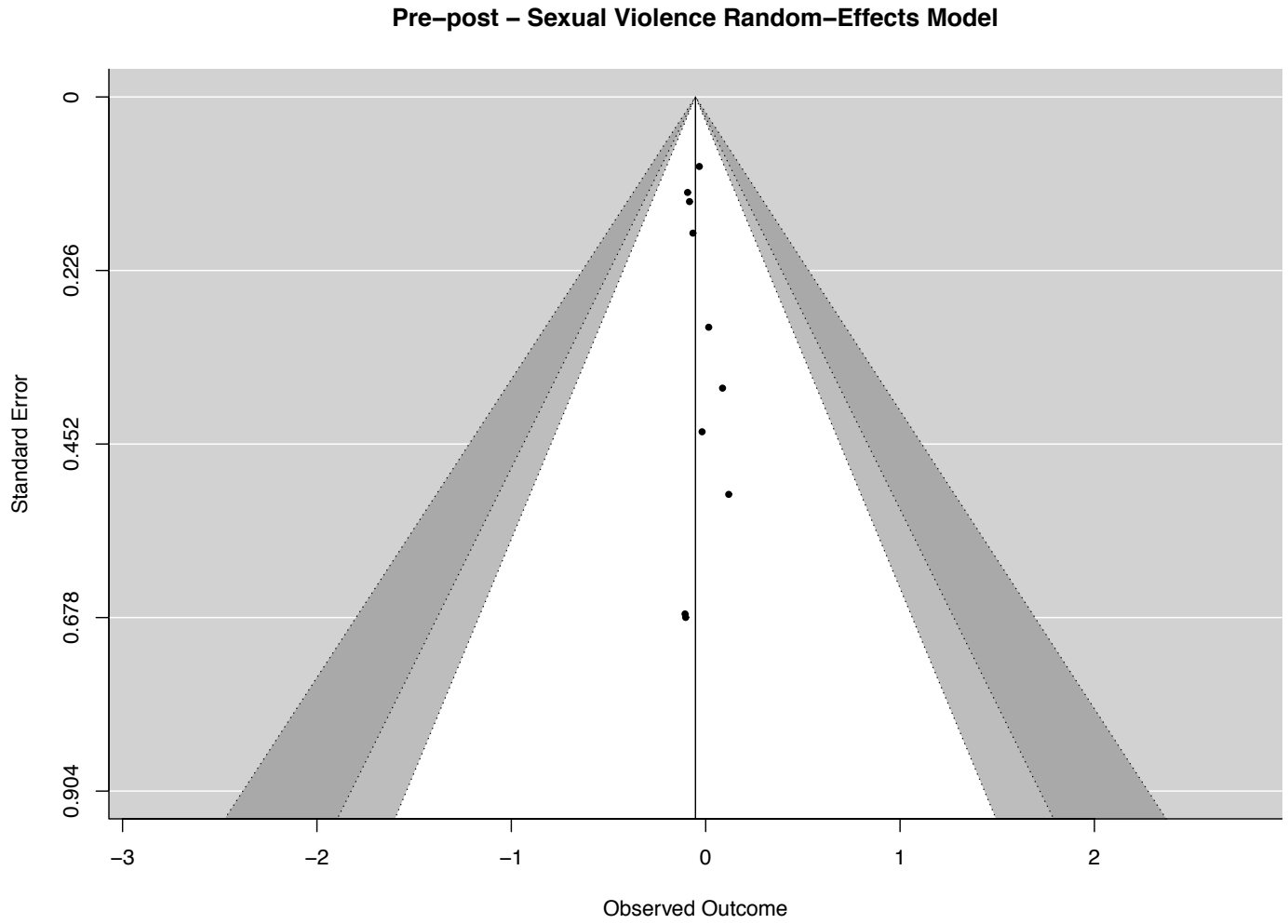
S11 Figure. All violence outcomes with pre-post design funnel plot



S12 Figure. Physical violence with pre-post design funnel plot



S13 Fig. Sexual violence with pre-post design funnel plot



Appendix C. Research paper 2 - supplementary materials

Appendix 1. List of literature repositories searched

Academic literature

Name
1. MEDLINE/PubMED
2. PsychINFO
3. Global Health
4. Social Policy and Practice
5. Scopus
6. Cumulative Index to Nursing & Allied Health Literature (CINAHL) Plus
7. Africa-Wide Information
8. Web of Science
9. International Bibliography of Social Sciences (IBSS)
10. Index Medicus for the Eastern Mediterranean Region (IMEMR)
11. Western Pacific Region Index Medicus (WPRIM)
12. Latin American and Caribbean Index Medicus (LILACS)
13. MedCarib
14. Indexing of Indian Medical Journals (IndMED)
15. China Academic Literature Database (CNKI English)

Grey literature

Name	Website
1. Humanitarian Response (Assessment reports; analysis reports; inter-agency humanitarian evaluation; and evaluation and lessons learned)	https://www.humanitarianresponse.info/
2. Save the Children Sweden – Resource Centre (Analysis; assessments; evaluations; reports; and studies, reviews, and research)	https://resourcecentre.savethechildren.net
3. Interagency Global Child Protection Area of Responsibility's website (Assessment reports and research)	http://cpwg.net/resource-topics/assessment-3/
4. Interagency Global Child Protection Area of Responsibility's website (Child Protection Sub-Cluster Coordinator starter packs)	http://cpwg.net/starter-packs/
5. IOM's online bookstore (International Migration Journal and studies and reports)	http://publications.iom.int/
6. UNHCR's website (Need assessments)	http://needsassessment.unhcr.org/tools-and-templates/

Appendix 2. PRISMA checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	Title page of the chapter, p. 123
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	Abstract, pp. 124-125
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	Introduction, pp. 125-127
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	Introduction, p. 127
METHODS			

Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	-
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	Methods, Search strategy, pp. 127-129
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	Methods, Search strategy, pp. 128-129 & Appendix 1
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Methods, Search strategy, p. 129
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	Methods, Selection and analysis, pp. 130-131 & Table 6, pp. 130-131

Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	Methods, Selection and analysis, pp. 130-131
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	Methods, Selection and analysis, pp. 130-131
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	Methods, Quality appraisal, pp. 131-132
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	Methods, Quality appraisal, pp. 131-132
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	Methods, Selection and analysis, pp. 130-131 & Quality appraisal, pp. 131-132

Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	Methods, Quality appraisal, pp. 131-132
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	-
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	Results, Characteristics of academic and grey literature, p. 132 & Fig 6, p. 134
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Results, Characteristics of academic and grey literature, pp. 132-135 & Table 7, p. 138

Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Appendix 3
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Results, Table 7, p. 138
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	Results, Pathways between natural disasters and violence against children, pp. 151-158
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	Results, Quality of evidence gathering and reporting practices, pp. 135-137

Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	-
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	Discussion, pp. 158-161
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	Discussion, Strengths and limitations, pp. 162-163
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	Discussion, Fig 6 p. 162, Implications for improving future practice, pp. 163-164 & Conclusion, p. 164
FUNDING			

Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	Title page of the thesis, p. 1

Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009; 6(6): e1000097. doi: 10.1371/journal.pmed1000097.

Appendix 3. Risk of bias rating for included academic and grey literature

1. Qualitative academic literature

Author	1	2	3	4	5	6	7	8	9	10	Quality score
Biswas et al. [474]	Y	Y	N	Not reported	N	N	N	N	Y	Y	4
Curtis et al. [66]	Y	N	N	Not reported	Not reported	N	Not reported	N	N	N	1
Davis and Bookey [476]	Y	Y	N	N	Not reported	N	N	N	N	N	2
Fisher [477]	Y	N	N	N	N	Not reported	Not reported	Not reported	Y	Y	3
Rashid and Michaud [242]	Y	Y	Y	Not reported	Y	Y	N	Y	Y	Y	8
Standing et al. [311]	Y	Y	N	N	N	N	N	N	Y	N	3

Y = Yes and N = No. 1. Aims of research; 2. Appropriate method; 3. Appropriate research design; 4. Appropriate recruitment strategy; 5. Appropriate data collection; 6. Relationship between researcher and considered adequately; 7. Ethical issues considered; 8. Data analysis rigorous; 9. Statement of findings; 10. Valuable research.

2. Quantitative cohort and cross-sectional study design in academic literature

Author	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Quality score
Biswas et al. [474]	Y	Y	Not reported	Y	Y	Y	Y	N	N	N	Y	N	N/A	Y	8
Catani et al. [100]	Y	Y	Not reported	Y	N	N	Not reported	Y	Y	N	Y	N	N/A	N	6
Scott et al. [152]	Y	Y	Y	Y	Y	N	N	Y	Y	N	Y	N	N/A	Y	9

Y = Yes, N = No, and N/A = Not Applicable. 1. Clear research question; 2. Clear study population; 3. Participation rate of greater than or equal to 50%; 4. Recruited from the same population, timeframe, and consistent inclusion/exclusion; 5. Sample size justified, power description, or variance and effect estimation; 6. Exposure before outcome; 7. Timeframe under a year; 8 Varying levels of exposure measured; 9. Clear and consistent exposure; 10. Exposure assessed more than once over time; 11. Clear and consistent outcome; 12. Assessors blinded; 13. Loss to follow up less than or equal to 20%; 14. Key confounders adjusted.

3. Quantitative case-control study design in academic literature

Author	1	2	3	4	5	6	7	8	9	10	11	12	Quality score
Terranova et al. [475]	Y	Y	N	N	N	Y	Y	Y	Y	Y	N/A	Y	8

Y = Yes, N = No, and N/A = Not Applicable.1. Clear research question; 2. Clear study population; 3. Sample size justified; 4. Same population and timeframe; 5. Consistent inclusion/exclusion; 6. Cases different from controls; 7. (if less than 100 cases or controls): random selection; 8. Concurrent controls; 9. Exposure before outcome; 10. Clear and consistent exposure; 11. Assessors blinded; 12. Key confounders adjusted or (if matching): proper statistics.

4. Qualitative grey literature

Author	1	2	3	4	5	6	7	8	9	10	Quality score
CARE Ethiopia [490]	Y	Y	Y	Not reported	Not reported	N	N	N	Y	Y	5
Child Protection Sub-Cluster [478]	Y	N	N	Y	Y	Not reported	Not reported	N	Y	Y	5
Civil Protection Zimbabwe [489]	Y	Y	Y	Not reported	Not reported	N	N	N	Y	Y	5

Government of Bangladesh and Humanitarian Coordination Task Team of Bangladesh [485]	Y	Y	Y	Y	Y	N	N	Y	Y	Y	8
International Federation of Red Cross and Red Crescent Societies [479]	Y	Y	Y	N	Y	N	N	Y	Y	Y	7
Jinks and Komenji [486]	Not reported	N	Not reported	Not reported	Not reported	Not reported	Not reported	N	Y	N	1

Ministry of International Affairs of the Government of the Kingdom of Tonga and Pacific Humanitarian Cluster [480]	Y	Y	Y	Not reported	Y	Not reported	Not reported	Not reported	Y	Y	6
Oxfam and CARE Ethiopia [494]	Y	Y	Y	Y	Y	N	N	Y	Y	Y	8

People in Need Czech Republic [481]	Y	Y	Y	Not reported	Y	N	N	N	Y	Y	6
People in Need Czech Republic [487]	Y	Y	Y	Y	Y	N	N	N	N	Y	6
Withers and Dalal [482]	Y	Y	Y	Y	Y	N	N	Y	Y	Y	8
Polack [491]	Y	Y	Not reported	Not reported	Not reported	N	N	N	Y	Y	4
Save the Children [483]	Y	Y	N	N	N	N	N	N	Y	Y	4

Save the Children [492]	Y	Y	Y	Not reported	Y	N	N	N	Y	Y	6
Save the Children [484]	Y	Y	Y	Not reported	Y	N	N	N	Y	Y	6
Save the Children [493]	Y	Y	N	Not reported	Not reported	N	N	N	Y	Y	4
United Nations Population Fund and Ministère à la Condition féminine et aux	Y	Y	N	Not reported	Not reported	Not reported	N	N	Y	Y	4

Droits des femmes [488]	

Y = Yes and N = No. 1. Aims of research; 2. Appropriate method; 3. Appropriate research design; 4. Appropriate recruitment strategy; 5. Appropriate data collection; 6. Relationship between researcher and considered adequately; 7. Ethical issues considered; 8. Data analysis rigorous; 9. Statement of findings; 10. Valuable research.

Appendix D. Research paper 3 - supplementary materials

Supplementary File 1. Violence outcome variables after the Haitian earthquake

Table S1. Violence outcome variables after the Haitian earthquake

1. Any form of physical violence by a parent, caregiver, adult relative, or other household member in the last 12 months (0=No, 1=Yes, 2=Missing)
2. Any form of physical violence by a public authority figure in the last 12 months (0=No, 1=Yes, 2=Missing)
3. Any form of emotional violence by a parent, caregiver, adult relative, or other household member in the last 12 months (0=No, 1=Yes, 2=Missing)
4. Any form of sexual violence by anyone in last 12 months (0=No, 1=Yes, 2=Missing)

The VACS asks four specific questions on behavioral acts for each overarching category of violence. Composite outcome variables were coded “yes” if the respondent answered, “yes” to any one of the affiliated survey questions; “no” if the respondent answered, “no” to all affiliated survey questions or a combination of “no” and skipped questions; and “missing” if the respondent skipped all affiliated questions.

Supplementary File 2. Pre-earthquake matching covariates for girls and boys

Table S2. Pre-earthquake matching covariates for girls

Covariates in propensity score matching	Response options	Affiliated survey questions
1. Age	0 – 13 1 – 14 2 – 15 3 – 16 4 – 17	F2. How old did you turn on your last birthday?
2. Living with biological mother	0 – No 1 – Yes	F16. How old were you when you last lived with [your biological mother]?
3. Single or double orphan	0 – No 1 – Yes	F19. How old were you when [your biological mother] died? + F25. How old were you when [your biological father] died?
4. Worked as a *restavek*	0 – No 1 – Yes	F13. How old were you when you

		began working as a Restavek for the first time?
5. Had sex for goods or money	0 – No 1 – Yes	F70. How old were you when you first exchanged money for sex? + F74. How old were you when you first exchanged food, gifts, or any favors for sex?
6. Punched, kicked, whipped, or beaten with object by a parent, caregiver, adult relative, or other household member	0 – No 1 – Yes 2 – Missing	How old were you when this first happened: 0-5, 6-11, 12-17, 18 or older? F201B. A parent, caregiver, any adult relative, or another adult household member punched you, kicked you, whipped you, or

		beat you with an object?
7. Single combined variable of choking, burning or threatening by a parent, caregiver, adult relative, or other household member	0 – No 1 – Yes 2 – Missing	How old were you when this first happened: 0-5, 6-11, 12-17, 18 or older? F202B. A parent, caregiver, any adult relative, or another adult household member choked you, smothered you or tried to drown you? + F203B. A parent, caregiver, any adult relative, or another adult household member burned or scalded you intentionally (including putting hot pepper in your

		mouth or on another body part)? + F204B. A parent, caregiver, any adult relative, or another adult household member used or threatened to use a knife or other weapon against you?
8. Punched, kicked, whipped, or beaten with object by a public authority figure	0 – No 1 – Yes 2 – Missing	How old were you when this first happened: 0-5, 6-11, 12-17, 18 or older? F207B. A public authority figure punched you, kicked you, whipped you, or beat you with an object?

9. Told not loved or did not deserve to be loved by a parent, caregiver, adult relative, or other household member	0 – No 1 – Yes 2 – Missing	How old were you when this first happened: 0-5, 6-11, 12-17, 18 or older? F301B. A parent, caregiver, any adult relative, or another adult household member said that you were not loved or did not deserve to be loved?
10. Had a parent, caregiver, adult relative, or other household member say that they wished that you were never born or dead	0 – No 1 – Yes 2 – Missing	How old were you when this first happened: 0-5, 6-11, 12-17, 18 or older? F302B. A parent, caregiver, any adult relative, or another adult household member said that they wished you

		had never been born or were dead?
11. Ridiculed or put down by a parent, caregiver, adult relative, or other household member	0 – No 1 – Yes 2 – Missing	How old were you when this first happened: 0-5, 6-11, 12-17, 18 or older? F303B. A parent, caregiver, any adult relative, or another adult household member ridiculed you or put you down (for example say that you were stupid or useless)?
12. Threated with abandonment or being forced to leave home by a parent, caregiver, adult relative, or other household member	0 – No 1 – Yes 2 – Missing	How old were you when this first happened: 0-5, 6-11, 12-17, 18 or older? F304B. A parent, caregiver, any adult relative, or another

		adult household member threatened to abandon you or threatened you that they would force you to leave home?
13. Single combined variable of touching without consent, attempted forced sex, pressured into sex, or forced sex by anyone	0 – No 1 – Yes	F402. Now think about the first time anyone touched you in a sexual way without your permission but did not try to force you to have sex. How old were you the first time this happened? + F504. Now think about the first time anyone tried to make you have sex without your permission but did not succeed. This could have been

		before or after the earthquake. How old were you the first time this ever happened? + F608. Now think about the first time anyone pressured you, in a nonphysical way, to have sex when you did not want to, and sex happened. This could have been before or after the earthquake. How old were you the first time this ever happened? + F704. Now think about the first time anyone physically forced you to have

		sex without your permission. This could have been before or after the earthquake. How old were you the first time this ever happened?

Pre-earthquake covariates were created by subtracting the respondent's current age at the time of the survey in 2012 from the age of occurrence of the covariate. A difference of three or more years in the past was categorized as before the 2010 earthquake. Composite covariates were coded "yes" if the respondent answered, "yes" to any one of the affiliated survey questions; "no" if the respondent answered, "no" to all affiliated survey questions or a combination of "no" and skipped questions; and "missing" if the respondent skipped all affiliated questions. Binaries were created for each response option. Covariates had to contain at least five individuals in the exposure or comparison group to be included in matching algorithm. Two girls were pregnant before the earthquake, and no girls were in a marriage-like relationship, so these covariates were not used in matching. The two pregnant girls as individual observations remained in the full analysis, because their propensity scores fell within the area of common support.

Table S3. Pre-earthquake matching covariates for boys

Covariates in propensity score matching	Response options	Affiliated survey questions
1. Age	0 – 13 1 – 14 2 – 15 3 – 16 4 – 17	M2. How old did you turn on your last birthday?
2. Living with biological mother	0 – No 1 – Yes 2 – Missing	M16. How old were you when you last lived with [your biological mother]?
3. Single or double orphan	0 – No 1 – Yes 2 – Missing	M19. How old were you when [your biological mother] died? + M25. How old were you when [your biological father] died?
4. Worked as a *restavek*	0 – No 1 – Yes 2 – Missing	M13. How old were you when you began working as a

		Restavek for the first time?
5. Had sex for goods or money	0 – No 1 – Yes 2 – Missing	M66. How old were you when you first exchanged money for sex? + M70. How old were you when you first exchanged food, gifts, or any favors for sex?
6. Punched, kicked, whipped, or beaten with object by a parent, caregiver, adult relative, or other household member	0 – No 1 – Yes 2 – Missing	How old were you when this first happened: 0-5, 6-11, 12-17, 18 or older? M201B. A parent, caregiver, any adult relative, or another adult household member punched you, kicked you, whipped you, or

		beat you with an object?
7. Single combined variable of choking, burning or threatening by a parent, caregiver, adult relative, or other household member	0 – No 1 – Yes 2 – Missing	How old were you when this first happened: 0-5, 6-11, 12-17, 18 or older? M202B. A parent, caregiver, any adult relative, or another adult household member choked you, smothered you or tried to drown you? + M203B. A parent, caregiver, any adult relative, or another adult household member burned or scalded you intentionally (including putting hot pepper in your

		mouth or on another body part)? + M204B. A parent, caregiver, any adult relative, or another adult household member used or threatened to use a knife or other weapon against you?
8. Punched, kicked, whipped, or beaten with object by a public authority figure	0 – No 1 – Yes 2 – Missing	How old were you when this first happened: 0-5, 6-11, 12-17, 18 or older? M207B. A public authority figure punched you, kicked you, whipped you, or beat you with an object?

9. Told not loved or did not deserve to be loved by a parent, caregiver, adult relative, or other household member	0 – No 1 – Yes 2 – Missing	How old were you when this first happened: 0-5, 6-11, 12-17, 18 or older? M301B. A parent, caregiver, any adult relative, or another adult household member said that you were not loved or did not deserve to be loved?
10. Had a parent, caregiver, adult relative, or other household member say that they wished that you were never born or dead	0 – No 1 – Yes 2 – Missing	How old were you when this first happened: 0-5, 6-11, 12-17, 18 or older? M302. A parent, caregiver, any adult relative, or another adult household member said that they wished you had

		never been born or were dead?
11. Ridiculed or put down by a parent, caregiver, adult relative, or other household member	0 – No 1 – Yes 2 – Missing	How old were you when this first happened: 0-5, 6-11, 12-17, 18 or older? M303. A parent, caregiver, any adult relative, or another adult household member ridiculed you or put you down (for example say that you were stupid or useless)?
12. Threated with abandonment or being forced to leave home by a parent, caregiver, adult relative, or other household member	0 – No 1 – Yes 2 – Missing	How old were you when this first happened: 0-5, 6-11, 12-17, 18 or older? M304. A parent, caregiver, any adult relative, or another

		adult household member threatened to abandon you or threatened you that they would force you to leave home?
13. Experienced any form of sexual violence (touching without consent, attempted forced sex, pressured into sex, forced sex)	0 – No 1 – Yes 2 – Missing	M402. Now think about the first time anyone touched you in a sexual way without your permission but did not try to force you to have sex. How old were you the first time this happened? + M504. Now think about the first time anyone tried to make you have sex without your permission but did not succeed. This could have been

		before or after the earthquake. How old were you the first time this ever happened? + M608. Now think about the first time anyone pressured you, in a nonphysical way, to have sex when you did not want to, and sex happened. This could have been before or after the earthquake. How old were you the first time this ever happened? + M704. Now think about the first time anyone physically forced you to have sex without your

		permission. This could have been before or after the earthquake. How old were you the first time this ever happened?

Pre-earthquake covariates were created by subtracting the respondent's current age at the time of the survey in 2012 from the age of occurrence of the covariate. A difference of three or more years in the past was categorized as before the 2010 earthquake. Composite covariates were coded "yes" if the respondent answered, "yes" to any one of the affiliated survey questions; "no" if the respondent answered, "no" to all affiliated survey questions or a combination of "no" and skipped questions; and "missing" if the respondent skipped all affiliated questions. Binaries were created for each response option. Covariates had to contain at least five individuals in the exposure or comparison group to be included in matching algorithm. No boys were in a marriage-like relationship, so this covariate was not used in matching.

Supplementary File 3. Balance tables for girls and boys

Table S4. Balance table for girls

Characteristic	Overall population	Before Match			After Match		
	Study population (N = 635)	Exposed (N = 157)	Comparison (N = 478)	Δ (SMD)	Exposed (N = 153)	Comparison (N = 153)	Δ (SMD)
Age – yr (%)	14.97 (100)	15.11 (24.7)	14.93 (75.3)	0.12	15.12 (50.0)	15.06 (50.0)	0.04
Living with biological mother – n (%)							
Yes	513 (80.8)	121 (19.1)	392 (61.7)	-0.12	119 (38.9)	122 (39.9)	-0.05
No	122 (19.2)	36 (5.7)	86 (13.5)	0.12	34 (11.1)	31 (10.1)	0.05

Single or double orphan – n (%)							
Yes	92 (14.5)	26 (4.1)	66 (10.4)	0.07	26 (8.5)	25 (8.2)	0.02
No	543 (85.5)	131 (20.6)	412 (64.9)	-0.07	127 (41.5)	128 (41.8)	-0.02
Restavek* **– n (%)**							
Yes	96 (15.1)	30 (4.7)	66 (10.4)	0.13	28 (9.2)	24 (7.8)	0.07
No	539 (84.9)	127 (20.0)	412 (64.9)	-0.13	125 (40.8)	129 (42.2)	-0.07
Exchanged sex for goods or money – n (%)							
Yes	11 (1.7)	6 (0.9)	5 (0.8)	0.14	3 (1.0)	3 (1.0)	0.00
No	624 (98.3)	151 (23.8)	473 (74.5)	-0.14	150 (49.0)	150 (49.0)	0.00
Punched, kicked, whipped, or beaten with object by adult – n (%)							
Yes	232 (36.5)	59 (9.3)	173 (27.2)	0.03	56 (18.3)	60 (19.6)	-0.05

No	335 (52.8)	81 (12.8)	251 (39.5)	-0.02	80 (26.1)	78 (25.5)	0.03
Missing	68 (10.7)	17 (2.7)	54 (8.5)	-0.02	17 (5.6)	15 (4.9)	0.04
All other forms of physical violence by adult – n (%)							
Yes	30 (4.7)	7 (1.1)	23 (3.6)	-0.02	7 (2.3)	4 (1.3)	0.09
No	601 (94.7)	149 (23.5)	452 (71.2)	0.02	145 (47.4)	148 (48.4)	-0.09
Missing	4 (0.6)	1 (0.1)	3 (0.5)	0.00	1 (0.3)	1 (0.3)	0.00
Punched, kicked, whipped, or beaten with object by public authority figure – n (%)							
Yes	79 (12.4)	22 (3.5)	57 (9.0)	0.06	20 (6.5)	14 (4.6)	0.12
No	536 (84.5)	130 (20.5)	406 (63.9)	-0.06	128 (41.8)	133 (43.5)	-0.09
Missing	20 (3.1)	5 (0.8)	15 (2.3)	0.00	5 (1.6)	6 (2.0)	-0.04

Told not loved or did not deserve to be loved by adult – n (%)							
Yes	51 (8.0)	16 (2.5)	35 (5.5)	0.09	14 (4.6)	13 (4.2)	0.02
No	571 (89.9)	137 (21.6)	430 (67.7)	-0.08	135 (44.1)	137 (44.8)	-0.04
Missing	13 (2.1)	4 (0.6)	13 (2.1)	-0.01	4 (1.3)	3 (1.0)	0.04
Had adult say that they wished that you were never born or dead – n (%)							
Yes	40 (6.3)	10 (1.6)	30 (4.7)	0.00	10 (3.3)	11 (3.6)	-0.03
No	584 (92.0)	141 (22.2)	437 (68.8)	-0.05	138 (45.1)	138 (45.1)	0.00
Missing	11 (1.7)	6 (1.0)	11 (1.7)	0.08	5 (1.6)	4 (1.3)	0.04
Ridiculed or put down by adult – n (%)							
Yes	51 (8.0)	16 (2.5)	35 (5.5)	0.09	15 (4.9)	11 (3.6)	0.09

No	563 (88.7)	135 (21.3)	426 (67.1)	-0.09	133 (43.5)	140 (45.8)	-0.14
Missing	21 (3.3)	6 (0.9)	17 (2.7)	0.01	5 (1.6)	2 (0.6)	0.11
Threated with abandonment or being forced to leave home by adult – n (%)							
Yes	15 (2.4)	6 (0.9)	9 (1.4)	0.10	5 (1.6)	3 (1.0)	0.07
No	610 (96.0)	149 (23.5)	457 (72.0)	-0.03	146 (47.7)	149 (48.7)	-0.09
Missing	10 (1.6)	2 (0.3)	12 (1.9)	-0.11	2 (0.7)	1 (0.3)	0.06
Experienced any form of sexual violence – n (%)							
Yes	34 (5.4)	16 (2.5)	18 (2.8)	0.21	14 (4.6)	17 (5.6)	-0.07
No	601 (94.6)	141 (22.2)	460 (72.5)	-0.21	139 (45.4)	136 (44.4)	0.07

SMD rounded up to two decimal places. “No” responses for binaries are not displayed in the love plot due to redundancy. The term *restavek* refers to a form of child slavery or extreme child labor found in Haiti.

Table S5. Balance table for boys

Characteristic	Overall population	Before Match			After Match		
	Study population (N = 758)	Exposed (N = 174)	Comparison (N = 584)	Δ (SMD)	Exposed (N = 172)	Comparison (N = 172)	Δ (SMD)
Age – yr (%)	14.82 (100)	14.92 (23)	14.80 (77)	0.08	14.92 (50.0)	15.88 (50.0)	0.03
Living with biological mother – n (%)							
Yes	614 (81.0)	133 (17.5)	481 (63.5)	-0.14	131 (38.1)	130 (37.8)	0.01
No	120 (15.8)	39 (5.1)	81 (10.7)	0.20	39 (11.3)	39 (11.3)	0.00
Missing	24 (3.2)	2 (0.3)	22 (2.9)	-0.24	2 (0.6)	3 (0.9)	-0.05

Single or double orphan – n (%)							
Yes	104 (13.7)	29 (3.8)	75 (9.9)	0.10	29 (8.5)	30 (8.7)	-0.02
No	629 (83.0)	138 (18.2)	491 (64.8)	-0.12	136 (39.5)	137 (39.8)	-0.01
Missing	25 (3.3)	7 (0.9)	18 (2.4)	0.05	7 (2.0)	5 (1.5)	0.06
Restavek* **– n (%)**							
Yes	78 (10.3)	28 (3.7)	50 (6.6)	0.20	27 (7.8)	28 (8.1)	-0.02
No	667 (88)	143 (18.9)	524 (69.1)	-0.20	142 (41.3)	142 (41.3)	0.00
Missing	13 (1.7)	3 (0.4)	10 (1.3)	0.00	3 (0.9)	2 (0.6)	0.04
Exchanged sex for goods or money – n (%)							
Yes	22 (2.9)	4 (0.5)	18 (2.4)	-0.05	4 (1.2)	5 (1.5)	-0.04
No	730 (96.3)	167 (22.0)	563 (74.3)	-0.02	166 (48.3)	165 (48.0)	0.03
Missing	6 (0.8)	3 (0.4)	3 (0.4)	0.09	2 (0.5)	2 (0.5)	0.00

Punched, kicked, whipped, or beaten with object by adult – n (%)							
Yes	318 (42.0)	76 (10.0)	242 (31.9)	0.05	74 (21.5)	72 (20.9)	0.02
No	299 (39.4)	75 (9.9)	224 (29.6)	0.10	75 (21.8)	74 (21.5)	0.01
Missing	141 (18.6)	23 (3.0)	118 (15.6)	-0.21	23 (6.7)	26 (7.6)	-0.05
Other forms of physical violence by adult – n (%)							
Yes	41 (5.4)	14 (1.8)	27 (3.6)	0.13	13 (3.8)	13 (3.8)	0.00
No	707 (93.3)	158 (20.8)	549 (72.4)	-0.11	157 (45.6)	156 (45.3)	0.02
Missing	10 (1.3)	2 (0.3)	8 (1.1)	-0.02	2 (0.6)	3 (0.9)	-0.05

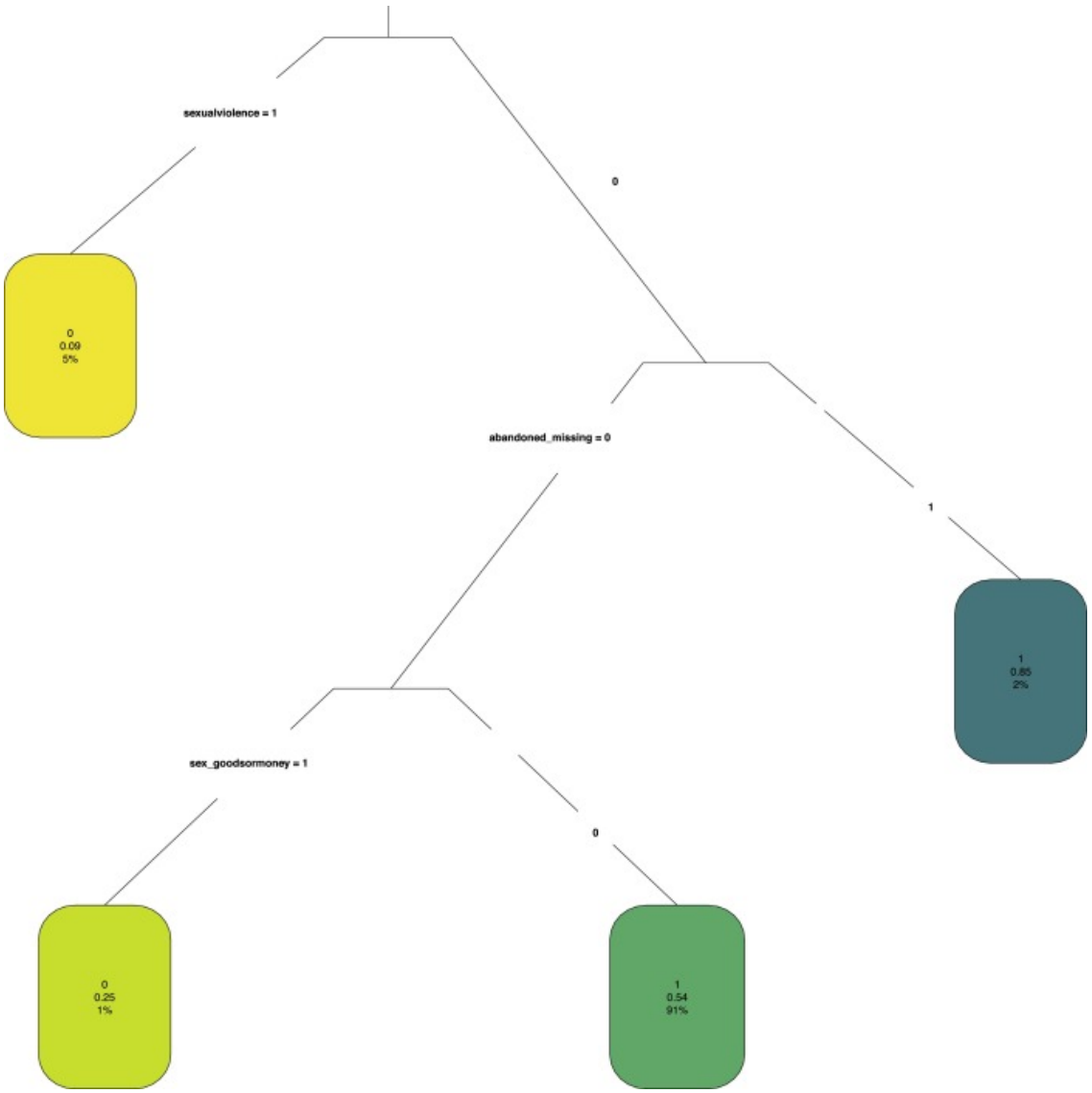
Punched, kicked, whipped, or beaten with object by public authority figure – n (%)							
Yes	123 (16.2)	20 (2.6)	103 (13.6)	-0.19	20 (5.8)	16 (4.6)	0.07
No	595 (78.5)	141 (18.6)	454 (59.9)	0.08	140 (40.7)	143 (41.6)	-0.04
Missing	40 (5.3)	13 (1.7)	27 (3.6)	0.11	12 (3.5)	13 (3.8)	-0.02
Told not loved or did not deserve to be loved by adult – n (%)							
Yes	72 (9.5)	14 (1.8)	58 (7.7)	-0.07	14 (4.1)	12 (3.5)	0.04
No	666 (87.9)	154 (20.3)	512 (67.6)	0.03	154 (44.8)	157 (45.6)	-0.06
Missing	20 (2.6)	6 (0.8)	14 (1.8)	0.06	4 (1.1)	3 (0.9)	0.04

Had adult say that they wished that you were never born or dead – n (%)							
Yes	53 (7.0)	13 (1.7)	40 (5.3)	0.02	13 (3.8)	10 (2.9)	0.07
No	685 (90.4)	155 (20.5)	530 (69.9)	-0.05	155 (45.0)	158 (45.9)	-0.06
Missing	20 (2.6)	6 (0.8)	14 (1.8)	0.06	4 (1.2)	4 (1.2)	0.00
Ridiculed or put down by adult – n (%)							
Yes	85 (11.2)	24 (3.2)	61 (8.0)	0.10	24 (7.0)	24 (7.0)	0.00
No	637 (84.0)	143 (18.9)	494 (65.2)	-0.06	141 (41.0)	141 (41.0)	0.00
Missing	36 (4.8)	7 (0.9)	29 (3.8)	-0.04	7 (2.0)	7 (2.0)	0.00

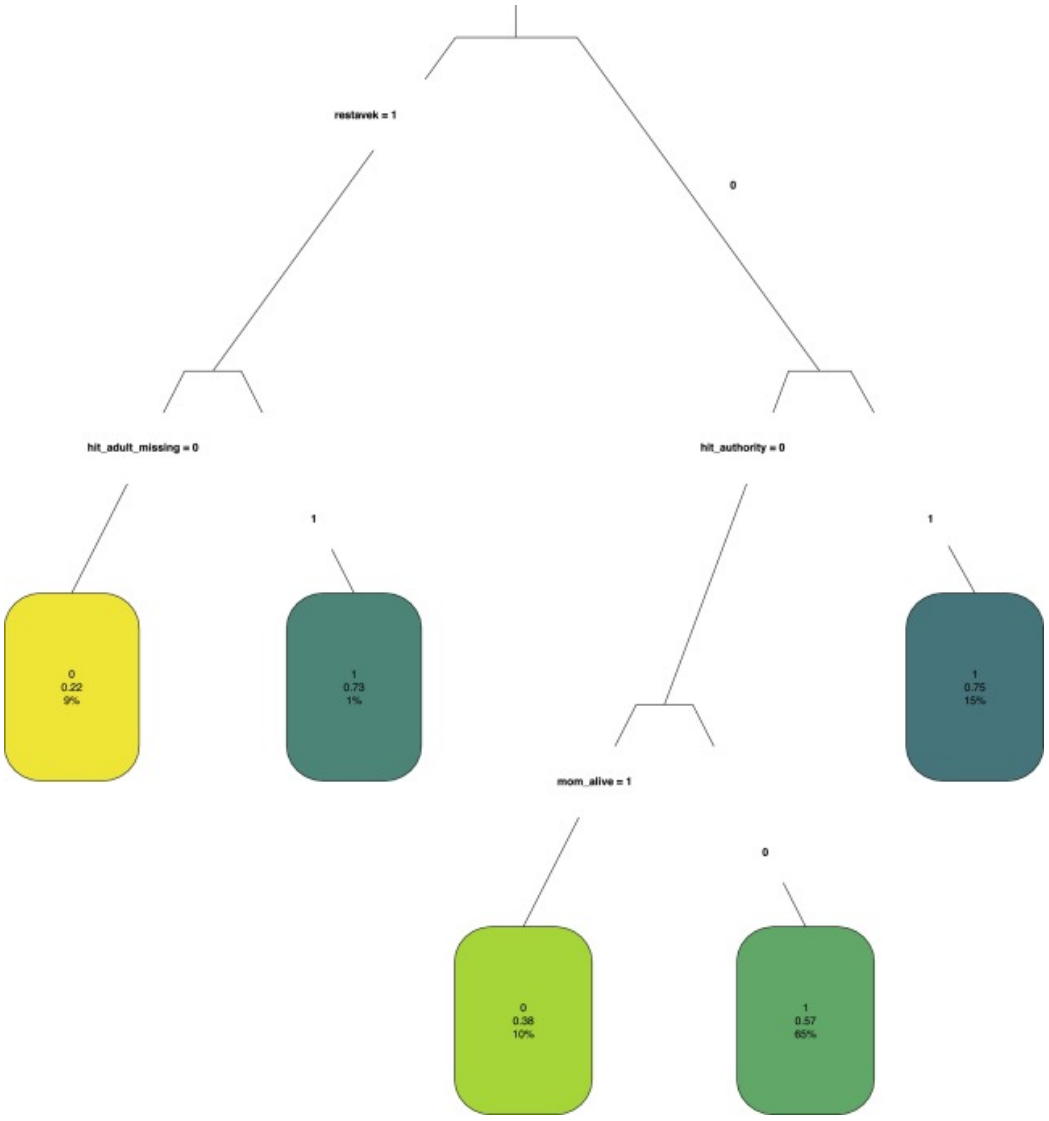
Threated with abandonment or being forced to leave home by adult – n (%)							
Yes	33 (4.4)	9 (1.2)	24 (3.2)	0.05	9 (2.6)	5 (1.4)	0.10
No	712 (93.9)	163 (21.5)	549 (72.4)	-0.01	161 (46.8)	165 (48.0)	-0.10
Missing	13 (1.7)	2 (0.3)	11 (1.4)	-0.07	2 (0.6)	2 (0.6)	0.00
Experienced any form of sexual violence – n (%)							
Yes	49 (6.5)	13 (1.7)	36 (4.7)	0.05	13 (3.8)	11 (3.2)	0.04
No	686 (90.5)	153 (20.2)	533 (70.3)	-0.10	151 (43.9)	155 (45.1)	-0.07
Missing	23 (3.0)	8 (1.1)	15 (2.0)	0.10	8 (2.3)	6 (1.7)	0.06

SMD rounded up to two decimal places. The term *restavek* refers to a form of child slavery or extreme child labor found in Haiti.

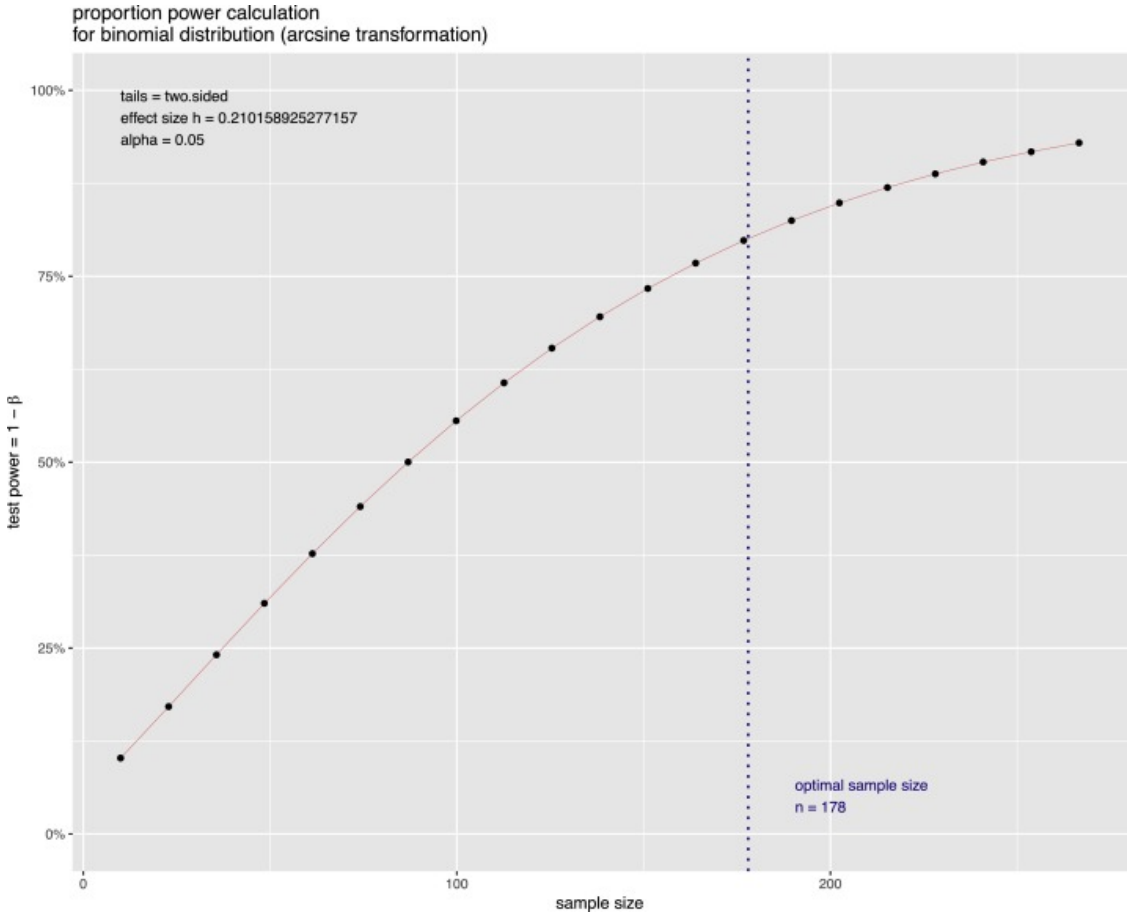
Supplementary File 4. Decision tree of the characteristics of the trimmed sample of girls



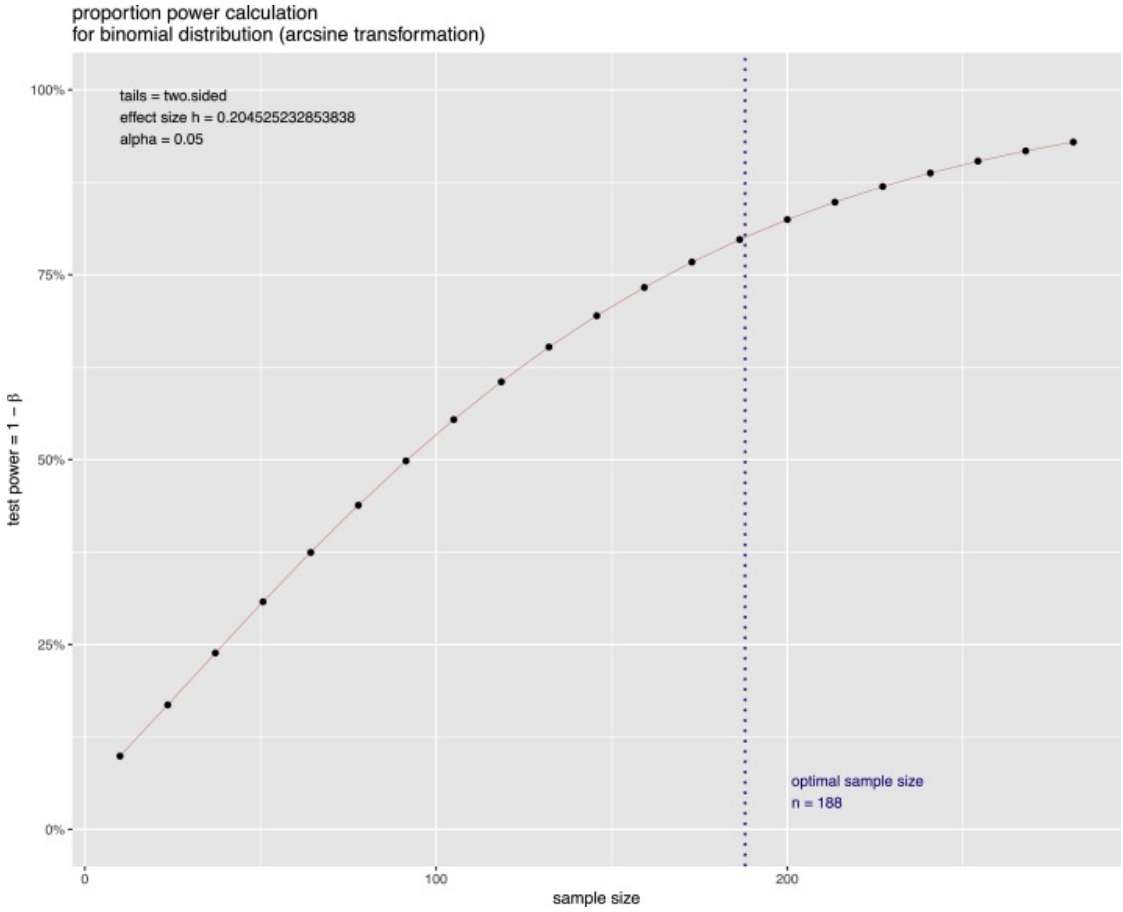
Supplementary File 5. Decision tree of the characteristics of the trimmed sample of boys



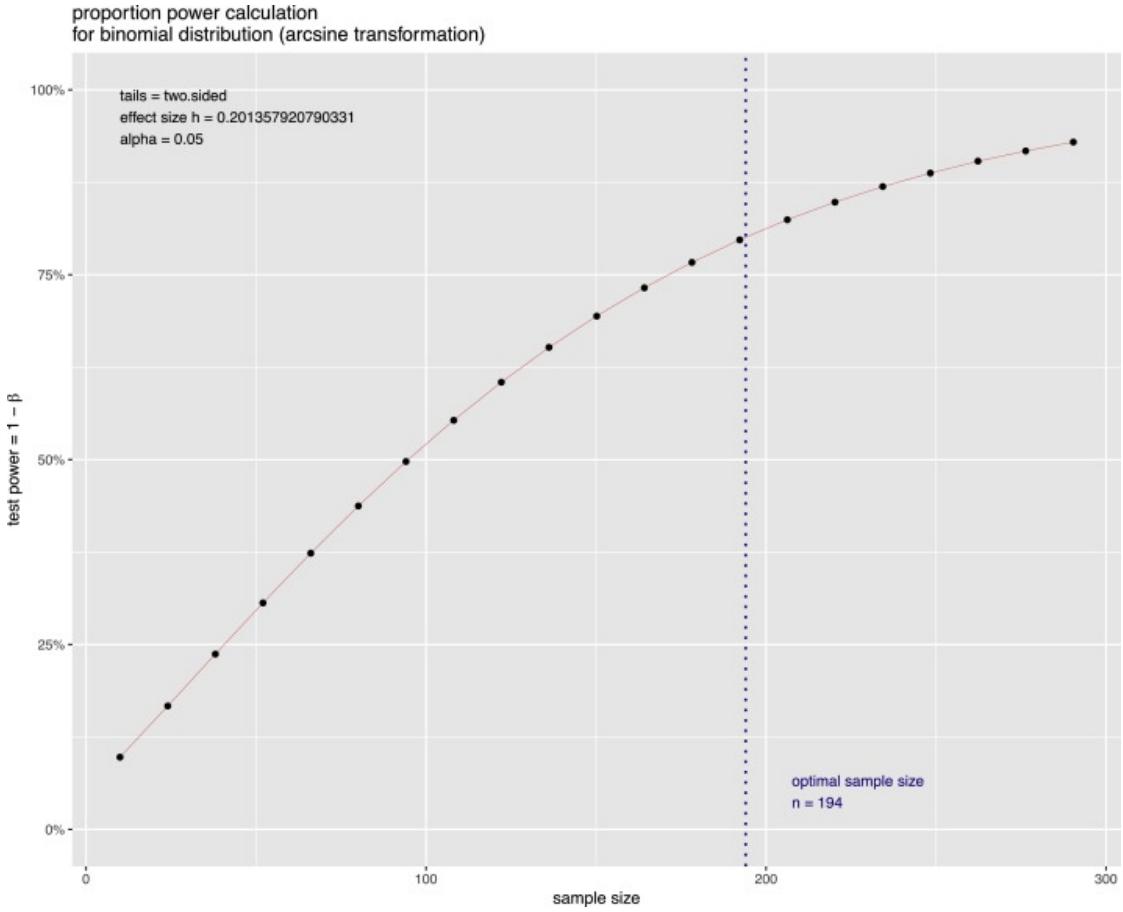
Supplementary File 6. Power calculation based on past estimates of all forms of violence in Haiti



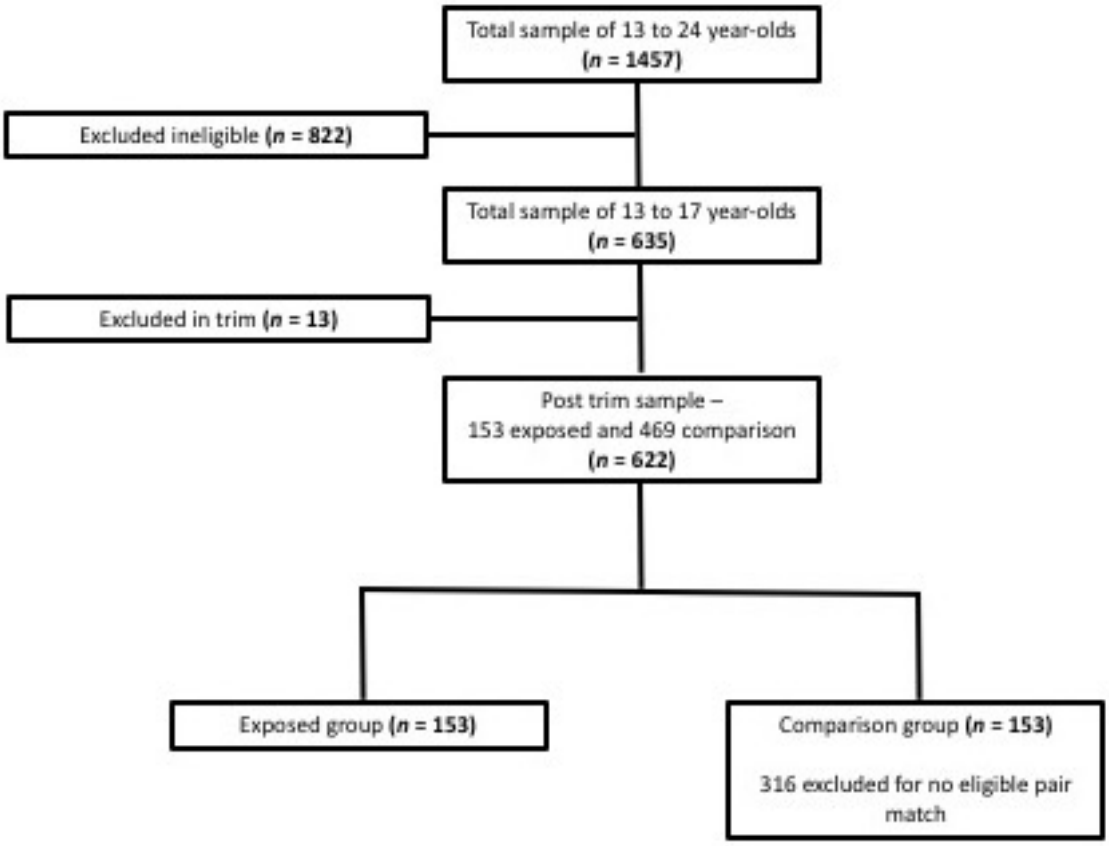
Supplementary File 7. Power calculation based on past estimates of corporal punishment of girls in Haiti



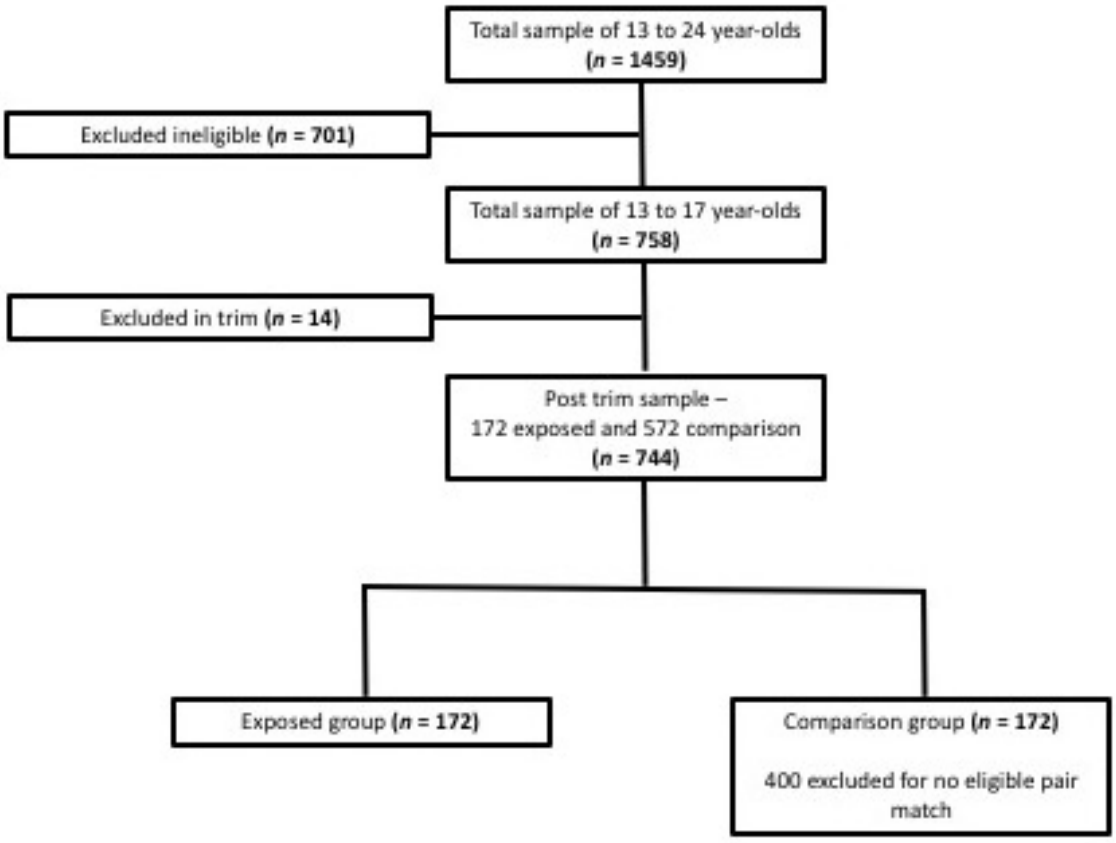
Supplementary File 8. Power calculation based on past estimates of corporal punishment of boys in Haiti



Supplementary File 9. STROBE chart of exposed and comparison groups used in matching for girls



Supplementary File 10. STROBE chart of exposed and comparison groups used in matching for boys



Supplementary File 11. Gamma sensitivity analyses for girls and boys

Table S6. Gamma sensitivity analysis for girls

Outcome	Gamma estimate	*p*-value
Physical Household	1.3	0.022
Physical Authority	2.0	0.043
Emotional	1.3	0.040
Sexual	1.1	0.048
Any form of violence	1.7	0.033

Table S7. Gamma sensitivity analysis for boys

Outcome	Gamma estimate	*p*-value
Physical Household	1.6	0.039
Physical Authority	1.2	0.045
Emotional	1.8	0.044
Sexual	1.7	0.042
Any form of violence	1.4	0.030

Gamma estimates were calculated using the `rbounds` package [622]. For most readers, the most interesting value will be the gamma itself—the larger values of the gamma parameter correspond to a result that is more robust to unobserved imbalances in covariates.

Appendix E. Research paper 4 - supplementary materials

Appendix 1. R code for Full-IV Matching

Set working directory and load data

```
setwd("~/Desktop")
d <- read.csv("dataframe.csv", header = TRUE)
```

Load needed libraries

```
library(MatchIt)
library(optmatch)
library(RItools)
library(lme4)
```

Review the pre-match balance of covariates

```
prebalancematch=xBalance(as.logical(exposure) ~ age +
as.logical(restavek) +
as.logical(parents) + as.logical(presexviol) + interaction + damage, s
trata = list(unstrat = NULL), report =
c("adj.means", "std.diffs"), data = d)

prebalancematch
```

Choose the cutoff points for the "far" values of the IV

```
l <- quantile(d$damage, .1) #bottom 10th percentile
u <- quantile(d$damage, .9) #top 90th percentile
```

Translate the low and high IV values

```
damage_nf <- ifelse(d$damage > max(d$damage), NA, NA) #remove NAs
damage_nf <- ifelse(d$damage <= l, d$damage[d$damage <= l], damage_nf)
damage_nf <- ifelse(d$damage >= u, ((d$damage[d$damage >= u]) - max(d$
damage) + min(d$damage)), damage_nf)

#hist(damage_nf, breaks = 100, main ="Translated IV values")

d$damage_nf <- damage_nf
```

Create a binary for the high and low values of the IV

```
damage_high <- ifelse(d$damage > max(d$damage), NA, NA) #remove NAs
damage_high <- ifelse(d$damage <= l, 0, damage_high)
damage_high <- ifelse(d$damage >= u, 1, damage_high)

d$damage_high <- damage_high
```

```
d_nf <- d[!is.na(damage_high), ]
```

Full-IV Matching

```
## Create the balance score for the IV
glm <- glm(damage_high ~ age + as.factor(restavek) + as.factor(parents
) +
            as.factor(presexviol) + interaction,
            family = binomial("logit"),
            data = d_nf)
summary(glm)

b_score <- predict.glm(glm)

#hist(b_score)

d2 <- cbind(d_nf, b_score)
d2 <- cbind(d_nf, damage_high[!is.na(damage_high)])



## Decide if trimming is needed for those outside of the area of commo
n
support
h1 <- b_score[d2$damage_high == 1]
length(h1)

h2 <- b_score[d2$damage_high == 0]
length(h2)

hist(h1, col=rgb(1,0,0,1), main="Overlapping histogram",
    xlab="Balance score of IV", breaks = 200)
hist(h2, col=rgb(0,0,1,0.5), add=T, breaks = 200)
box()



## Left tail of histogram
hist(h1, col=rgb(1,0,0,1), xlim=c(-.5,1), ylim=c(0,100), main="Overlap
ping
histogram", xlab="Balance score of IV", breaks = 20)
hist(h2, col=rgb(0,0,1,0.5), add=T, breaks = 20)
box()


## Right tail of histogram
hist(h1, col=rgb(1,0,0,1), xlim=c(0,1.5), ylim=c(0,100), main="Overlap
ping
histogram", xlab="Balance score of IV", breaks = 20)
hist(h2, col=rgb(0,0,1,0.5), add=T, breaks = 20)
box()



## Full matching using mahalanobis distance
distmat <- match_on(as.logical(damage_high) ~ damage_nf + b_score,
                        method = "mahalanobis", data = d2)
```

```
distmatfull <- fullmatch(distmat, min.controls = (1/6), max.controls =
6,
data = d2)

summary(distmatfull)
d3 <- cbind(d2, distmatfull)
```

Review the post-match balance after Full-IV Matching

```
postbalance <- xBalance(as.logical(damage_high) ~ damage_nf + age +
as.logical(restavek) + as.logical(parents) + as.logical(presexviol) +
interaction + damage, report = c("adj.means", "std.diffs",
"adj.mean.diffs.null.sd"), data = d3)
postbalance
```

Inference

```
## GLMM
IV <- lme4::glmer(outcome ~ damage_high + (1|distmatfull), family = bi
nomial, data = d3)
summary(IV)

## Bootstrap confidence interval
ciIV <- confint(IV, parm="beta_", level = 0.95,
        method = c("boot"),
        nsim = 500,
        boot.type = c("basic"))
```

Notes

- Individuals within the same IV quantile cannot be matched to each other.
- In our example, trimming is not needed for this dataset. If trimming is needed, it is important to refit the balance score to the trimmed dataset before matching.