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Earthquake severity and child nutrition: The Haiti 2010 earthquake

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ABSTRACT

Nutritional status is an important indicator of children's health and well-being. Previous research on child nutrition in earthquake contexts has shown an increased chance of undernutrition among children in affected areas. Haiti suffered a devastating earthquake in January 2010. This paper makes an important addition to previous research by investigating variations in child nutrition (height-for-age z-scores) across birth cohorts and earthquake severity. Data from Haiti Demographic and Health Surveys from 2005–06, 2012 and 2016–17 and geocoded data on the Modified Mercalli Intensity scale and the Peak Ground Acceleration from the U.S. Geological Survey are analysed with linear regression. The results show that children born in some of the post-earthquake years located in areas with severe earthquake impact had lower HAZ relative to children in less impacted areas. It is especially important to ensure a well-coordinated response after major disasters to reduce the impact on child undernutrition, not only in the immediate aftermath but also in the long term.

1. Introduction

Children are highly vulnerable to natural hazard related disasters, normally accounting for half of the affected population (Peek, 2008; Kousky, 2016). Low-income countries carry the heaviest burden of such disasters, and children in these settings tend to be even more vulnerable and consequently more likely to suffer long-lasting effects (Currie and Vogl, 2013; Kousky, 2016). Poor countries that frequently suffer natural hazard related disasters might experience structural challenges that can slow down development in child health indicators. Disaster impacts on health are likely to be larger in these countries, not only because the disasters happen more frequently, but also because the lasting effects of adverse health in early life may be more important and the context could make it more challenging to catch up or recover (Currie and Vogl, 2013). One frequently observed child health outcome after natural hazard related disasters is undernutrition, which is an important determinant of child health and well-being (Black et al., 2008; de Onis and Branca, 2016; Agabiirwe et al., 2022; Hossain, Khan and Parvez, 2022). Inadequate nutrition in early life increases a child's risk of dying from infections and could lead to irreversible damage to the child's future, for instance poor cognition and educational performance, adverse adult disease susceptibility, and reduced adult income (Black et al., 2008; Victora et al., 2008; de Onis and Branca, 2016).

Haiti, the poorest country in Latin America and the Caribbean region, suffered a major earthquake in January 2010. Given the country's economic context and Haitian children's pre-existing vulnerability to undernutrition, previous reports of the impact of the 2010 earthquake on child nutrition have been puzzlingly contradictory. Descriptive findings indicated improvement in child undernutrition indicators between 2005–06 and 2012, which capture the periods before and right after the earthquake, and limited or no improvements in child undernutrition between 2012 and 2016–17 (Ayoya et al., 2013, 2014; Evans and Bassani, 2018; Institut Haïtien de l'Enfance (IHE) and ICF, 2018). However – in line with the general literature showing an increased risk of child undernutrition after earthquakes (Hamid, Bhakta and Gilchrist, 2008; Bustelo, Arends-Kuenning and Lucchetti, 2012; Sun et al., 2013; Dong et al., 2014b, 2014a; Thamarapani, 2016; Frankenberg et al., 2017; Dhoubhadel et al., 2020; Shrestha et al., 2020; Ogasawara, 2021) – Dodlova and colleagues (2023) found with a differences-in-differences design of periods before and after the earthquake that exposure to stronger shaking had a negative effect on nutrition outcomes in a dose–response relationship.

This study contributes to further understanding the effects of natural disasters on child nutrition and development by analysing the effects of the Haiti 2010 earthquake intensity on undernutrition of birth cohorts born before and after the earthquake. Life course epidemiological theories stress that the prenatal and early childhood periods are sensitive periods for children's development and nutrition shocks during this

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developmental period are particularly likely to have long-term effects on their growth. The population living in areas that were affected the most by the earthquake suffered not only from immediate stress and destruction, but also from longer-term economic and health effects (such as the cholera epidemic that followed) of the severe earthquake. Children born before and after the earthquake were differently susceptible to these effects depending not only on whether they lived in more or less affected areas, but also whether they were exposed during the sensitive developmental periods. By exploiting the geographical variation in earthquake intensity and in children's developmental periods, the cohort design applied in this study allows for theoretically motivated measurements of exposure to earthquake intensity and its aftermaths and complements findings that have identified earthquake effects by using period designs that pool together children across various ages (Dodlova et al., 2023).

This study leverages data on children's nutritional status – measured as height-for-age – from the Haiti Demographic and Health Surveys (DHS) and geolocated measures of earthquake intensity measured through the Modified Mercalli Intensity scale (MMI) and the Peak Ground Acceleration (PGA). MMI captures earthquake intensity through observations and personal reports on the ground whereas PGA is an instrumental measurement indicating the maximum acceleration rate during the earthquake. The results show that children born after the earthquake in the most severely hit areas showed compromised growth compared to children located in less affected areas. The results suggest that the earthquake and its aftermath had the strongest effect on children exposed to them from birth.

2. Theory and previous studies

Height-for-age is a good indicator of the nutritional conditions and disease environment of childhood, and a summary measure of health-related circumstances and events (Elo and Preston, 1992). When height is two standard deviations below the average (low height-for-age) it is referred to as stunting (Black et al., 2013), which is an indicator of chronic nutritional deprivation (Behrman, Alderman and Hoddinott, 2004). Stunting often begins while the child is in utero and it continues until at least the age of two years, which is referred to as the first 1,000 days (Black et al., 2013; de Onis and Branca, 2016). Good nutrition and healthy growth are especially important during this period to establish lifelong, lasting benefits (Martorell, 1999; Black et al., 2013). Barker's fetal origins hypothesis has linked the nutritional conditions during the in-utero period to diseases in adulthood (Barker, 1995). Challenging conditions and food insecurity for the mother can therefore have long term consequences for the unborn child.

Children who experience stunting before the age of two to three years are more likely to have challenges with poorer cognitive and educational outcomes later in life (Martorell, 1999; Black et al., 2013). Growth retardation and poor cognition share determinants such as suboptimal nutrition, inadequate care, and repeated infections (Leroy and Frongillo, 2019). Healthy growth could make the child more resistant to infections, which can reduce the risk of mortality (De Onis and Blossner, 1997; Black et al., 2008). Children who have suffered from stunted growth in early life could suffer irreversible damage, such as lower educational attainment, reduced adult income, and decreased offspring birthweight (Victora et al., 2008). Hence, stunted growth in early life may not only have an immediate effect on the child's health but could also generate negative implications into adulthood and be passed on to the next generation. Children exposed to inadequate environments are more likely to experience linear growth retardation and stunting (Leroy and Frongillo, 2019). Areas with high prevalence of growth retardation and stunting imply that there is a deficient growth environment and children in these environments are unlikely to reach their full developmental and economic potential in the future (Leroy and Frongillo, 2019).

Whether catch-up growth is possible has been debated and depends on the definition of catch-up as well as the environment in which the child is living (Desmond and Casale, 2017; Frankenberg et al., 2017; Schneider, Ogasawara and Cole, 2021). The first 1,000 days can therefore be a critical or sensitive period. A critical period of development in life course epidemiology is defined as a limited time window wherein an exposure can have irreversible adverse or protective effects on development and disease outcomes, and a sensitive period is a time window in which effects of an exposure are particularly strong but unlike in the case of critical periods, the effects are not irreversible but allow for their modification or reversal outside of the time window (Ben-Shlomo, Mishra and Kuh, 2014).

Children who have been exposed to an earthquake (or its aftermaths) in early life have an increased risk of being undernourished. This outcome has been shown both for children who were exposed while in utero (Thamarapani, 2016; Frankenberg et al., 2017; Ogasawara, 2021) and also for children exposed directly or indirectly in their first years of life (Hamid, Bhakta and Gilchrist, 2008; Bustelo, Arends-Kuenning and Lucchetti, 2012; Sun et al., 2013; Dong et al., 2014b, 2014a; Andrabi, Daniels and Das, 2020; Dhoubhadel et al., 2020; Shrestha et al., 2020). Conversely, one study of the 2015 Nepal earthquake found unchanged prevalence of under-five stunting and mean height-for-age z-scores one year after the earthquake compared to one year before the earthquake (Thorne-Lyman et al., 2018). In previous research on earthquakes and child undernutrition, outside Haiti, the geographical impact of the earthquake has been included by separating areas into affected and not affected (Bustelo, Arends-Kuenning and Lucchetti, 2012; Thamarapani, 2016; Frankenberg et al., 2017) or by comparing figures from affected areas to those from the same area before the earthquake, relevant national averages, or standards from the World Health Organization (WHO) (Hamid, Bhakta and Gilchrist, 2008; Sun et al., 2013; Dong et al., 2014b, 2014a; Thorne-Lyman et al., 2018; Dhoubhadel et al., 2020; Shrestha et al., 2020). Two studies have applied a combination of these measures to identify the geographical areas more or less affected by the earthquake (Andrabi, Daniels and Das, 2020; Ogasawara, 2021). The majority of studies on child stunting and earthquakes indicate an increased risk of stunting after the earthquake for children living in affected areas. However, whether this impact persists over time or varies with earthquake severity are less clear. Results from two studies have indicated a negative effect one to two years after the disaster, which was then found to have disappeared five to six years after the earthquake (Bustelo, Arends-Kuenning and Lucchetti, 2012; Frankenberg et al., 2017). Other studies have found a negative impact ten months to four years after the disaster (Hamid, Bhakta and Gilchrist, 2008; Sun et al., 2013; Dong et al., 2014b, 2014a; Andrabi, Daniels and Das, 2020; Dhoubhadel et al., 2020; Shrestha et al., 2020), while two studies have found a long-term negative impact, eight years or longer after the earthquake (Thamarapani, 2016; Ogasawara, 2021).

2.1. Haiti and the 2010 earthquake

On January 12, 2010, an earthquake hit the Caribbean island of Haiti, where the population was already suffering from poverty and political instability. The earthquake affected over 1.5 million people, with children and youth accounting for more than one-half of those affected (Dube et al., 2018). The 2010 earthquake was the most damaging seismic event over the last 200 years in this region, with more than 222,000 deaths estimated according to the Emergency Events Database (EM-DAT).[1] The epicentre was about 20 km from Port-au-Prince, resulting in great suffering for the densely populated capital (Farmer et al., 2012; Katz, 2013). Additionally, in October the same year, Haiti also faced a major cholera epidemic, which spread quickly among the already vulnerable population (Barzilay et al., 2013; Luquero et al., 2016). The epidemic reached all ten departments (administrative

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[1] The Emergency Events Database: https://public.emdat.be.

divisions) of Haiti, and has remained a serious public health challenge since the earthquake (Barzilay et al., 2013; Ivers, 2017). Both disasters have taken their toll on children in Haiti. Thus, one would expect a negative impact on child undernutrition as a consequence of the devastating 2010 earthquake.

Descriptive studies and reports on trends in stunting in Haiti have reported improvements in stunting between 2005–2006 and 2012, despite the devastating 2010 earthquake and cholera outbreak (Ayoya et al., 2013, 2014; Evans and Bassani, 2018). However, the overall prevalence of child undernutrition in Haiti was still considered high in 2012 even with a decline in stunting from approximately 29 % to 22 % (Ayoya et al., 2013; Evans and Bassani, 2018; Institut Haïtien de l'Enfance (IHE) and ICF, 2018) and the prevalence has later remained stable at 22 % in 2016–17 (Institut Haïtien de l'Enfance (IHE) and ICF, 2018). Although these trend analyses compare the period before and after the 2010 earthquake, they do not tell about the effects of the earthquake. Dodlova and colleagues (2023) analysed these effects using four DHS survey waves and geographical variation in the intensity of the earthquake, finding that geographical exposure to more severe earthquake increased the prevalence of stunting and wasting and reduced children's school enrolment and attendance.

Other studies have highlighted that the earthquake affected households differently, for instance that the poorest were more affected (Herrera et al., 2014). This can compound existing inequalities and made the population more vulnerable to other shocks. The humanitarian aid provided after the earthquake was short-term and did not make it possible to ensure a sustainable improvement in living conditions, and calls have been made for more targeted approaches, for instance towards victims in Port-au-Prince and camps than victims outside the most affected department (Herrera et al., 2014; Saint-Macary and Zanuso, 2016). The earthquake has been associated with persistent welfare loss over time as well as a long-lasting negative impact on labour market participation, especially for populations in the most affected areas (Saint-Macary and Zanuso, 2016). Children's education and time allocation has also been shown to change as a consequence of the earthquake, with larger chances of working and lower chances of studying for school-age children (Novella and Zanuso, 2018) and lower school enrolment and attendance (Dodlova et al., 2023). These studies imply a negative impact on socioeconomic outcomes for those most affected by the 2010 earthquake. Socioeconomic consequences of natural hazard related disasters can lead to food insecurity in affected communities (Gaire et al., 2016; Hossain, Khan and Parvez, 2022).

3. Data and analysis

3.1. Demographic and health Surveys

This study analyses cross-sectional, nationally representative data from the 2005–06, 2012, and 2016–17 Haiti DHS, which can be accessed through the DHS Program.[2] The Haiti DHS also contains latitude, longitude and elevation data for clusters; in urban areas, a cluster is usually a city block, while in rural areas clusters can be an entire village, a part of a larger village, or a group of small villages (ICF International, 2012). The clusters are geomasked to ensure respondents' confidentiality. Thus, urban clusters are displaced a distance up to two kilometres and rural clusters are displaced a distance up to five kilometres, and additionally a randomly-selected 1 % of rural clusters are displaced a distance up to 10 km (Burgert et al., 2013). Preselected households are interviewed as part of the normal sampling procedures for DHS, and there are no replacements or changes to these preselected homes (ICF International, 2012). After a disaster, such as the Haiti 2010 earthquake, one would expect several damaged houses, especially for the 2012 survey. Households who previously inhabited houses that were damaged by the earthquake are therefore not expected to have been replaced with households whose housing is not damaged, so if houses are uninhabitable the data from these households would most likely be missing from the sample. Information on years lived in current location at time of interview is missing from the 2012 survey wave but included in the 2005–06 and 2016–17 survey waves. Some of the households from the 2012 survey wave were identified as located in official camps, though this information was only collected for this survey wave.

Women of reproductive age from 15 to 49 years were interviewed, while the unit of analysis for this paper is children (of women interviewed) who were born in the five years preceding each survey. The datasets contain anthropometric measures on children taken at the time of the interview. Additionally, the surveys collected data on the mothers, including information on pregnancy and postnatal care. After excluding clusters without geocoded references (255 children) and children without anthropometric measures (2,738 children in 2005–2006 survey, 3,263 children in 2012 survey, and 947 children in 2016–17 survey), a total of 11,975 children under age five were included in the analysis.

3.2. U.S. Geological survey

Two earthquake severity measures are included, and both are obtained from the USGS (U.S. Geological Survey) and consist of ShakeMaps with polygons (USGS, 2017). The Modified Mercalli Intensity scale (MMI) is included as a categorical variable and describes the effect of an earthquake on the surface of the earth. The ranking is indicated by Roman numerals ranging from I to X, where the lowest value indicates imperceptible shaking and the highest indicates catastrophic destruction (Table 1 and Fig. 1). The MMI is a meaningful measure for social scientists and captures variations in how the earthquake affected both infrastructure and people, hence the scale captures the perceived effects (Mendonça, Bilgin and Wolke, 2019). The Peak Ground Acceleration

Table 1
Modified Mercalli Intensity scale (USGS, 2019).

Intensity	Shaking	Description/Damage
I	Not felt	Not felt except by a very few under especially favourable conditions.
II	Weak	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognise it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

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[2] DHS Program: https://dhsprogram.com/data/available-datasets.cfm.

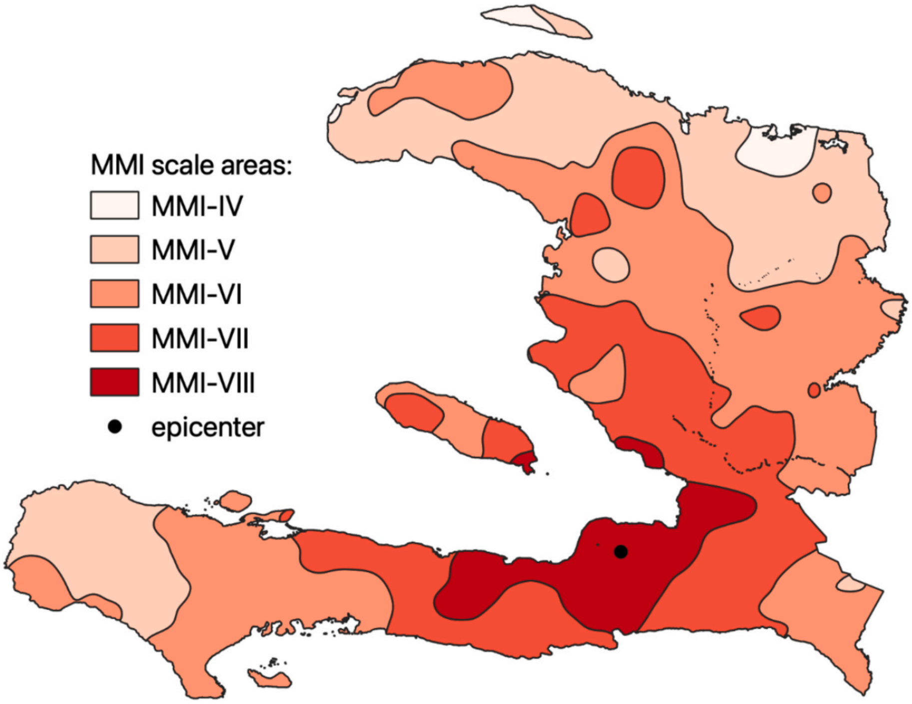

Fig. 1. Map of Haiti with MMI areas and epicentre.

(PGA) is explored as a continuous measure of the earthquake exposure and captures the local specific hazard exposure measured through maximum acceleration experienced on the ground during the earthquake (Saint-Macary and Zanuso, 2016). A PGA of 0.1 g (or 10 %g) is considered a weak impact, while 0.4 g (or 40 %g) and above indicate severe earthquake impact. A spatial join of MMI and PGA polygons and the geocoded DHS clusters was conducted with the software QGIS (Fig. 1-3). The earthquake severity for the children in the sample was identified by combining the geographical point location of each of the DHS clusters and the polygons of the MMI and PGA areas.

3.3. Variables

The anthropometric measure height-for-age is considered the best indicator of whether a child is growing as expected and it is associated with delayed child development, reduced earnings at adulthood, and chronic diseases (Pörtner, 2010; Leroy and Frongillo, 2019). Linear growth retardation or stunting imply that the child does not receive a sufficient diet or proper care to be healthy, which could depend on a range of determinants such as food insecurity, caregiver's nutrition, health literacy, and access and utilisation of health services (Leroy and Frongillo, 2019). The WHO has established growth standards for children, which can be used as a reference by converting the height-for-age measures to z-scores (WHO, 2006). WHO Child Growth Standards are a technically robust tool to consider the well-being of infants and young children (WHO, 2006). The standards are based on normal early childhood growth in optimal environmental conditions, and can therefore be used to assess children regardless of ethnicity or socioeconomic status (WHO, 2006). The dependent variable height-for-age z-scores (HAZ) are computed based on WHO growth standards, and in this sample range from -5.92 to 6. The z-score variable is already calculated and included in the DHS data files. A complicated interpolation has been conducted to estimate the z-scores, where sex, age, and height in centimetres are taken into account (Croft, Marshall and Allen, 2018).

Two measures of earthquake severity are applied as independent variables. The MMI variable ranges from IV/V to VIII (Table 1 and Fig. 1). MMI IV and V are combined since there were very few clusters located in MMI IV, and both were less affected compared to the other areas. The MMI variable is included as a categorical variable and ranges from 0 to 3, where the reference category is the least affected area (MMI IV/V). The PGA variable is included as a continuous measure ranging from 0.02 g to 1.34 g (Fig. 3).

The second independent variable(s) is the birth year of the children, which is included in order to observe the trend over time. Anthropometric measures were taken for children aged five or younger at the time of the interview, which means the inclusion of children born no more than five years prior to the survey wave. Children measured in 2005–06 were not affected by the earthquake, while children measured in 2012 and 2016–17 may have been affected indirectly or directly by the earthquake depending on geographical location (Fig. 4). For children measured in 2012, the oldest children are born in 2007. Children born from 2007 onwards were all affected by the earthquake either through direct exposure at early ages (born in 2007–2009) or in utero (born in 2010), or by the long-term socioeconomic and development impact of the earthquake. A set of binary variables for birth year cohort were included for children born 2003–2017. Children born 2000–2002 are kept as the reference category (869 children[3]). The cohorts 2000, 2001, and 2002 were combined to one reference category since very few children (8) were born in 2000 and exploring birth cohorts seven years after and seven years before the earthquake creates a good overview of the birth cohorts both pre and post the 2010 earthquake.

Based on the empirical evidence that it is the first 1,000 days that matters the most, applying a birth cohort design in combination with the geographical location according to MMI and PGA areas will make it possible to identify the cohorts exposed or not. Therefore, it is possible to estimate the effect of the earthquake severity on child nutrition.

The 2012 survey wave includes some earthquake-specific questions at the household level, which indicate a similar earthquake impact as the MMI areas. Additionally, the cholera outbreak might have had a stronger impact on areas less affected by the earthquake, since these areas were closer to the source of the outbreak. The proportion of children of

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[3] 8 children from 2000 cohort, 379 children from 2001 cohort, and 482 children from 2002 cohort.

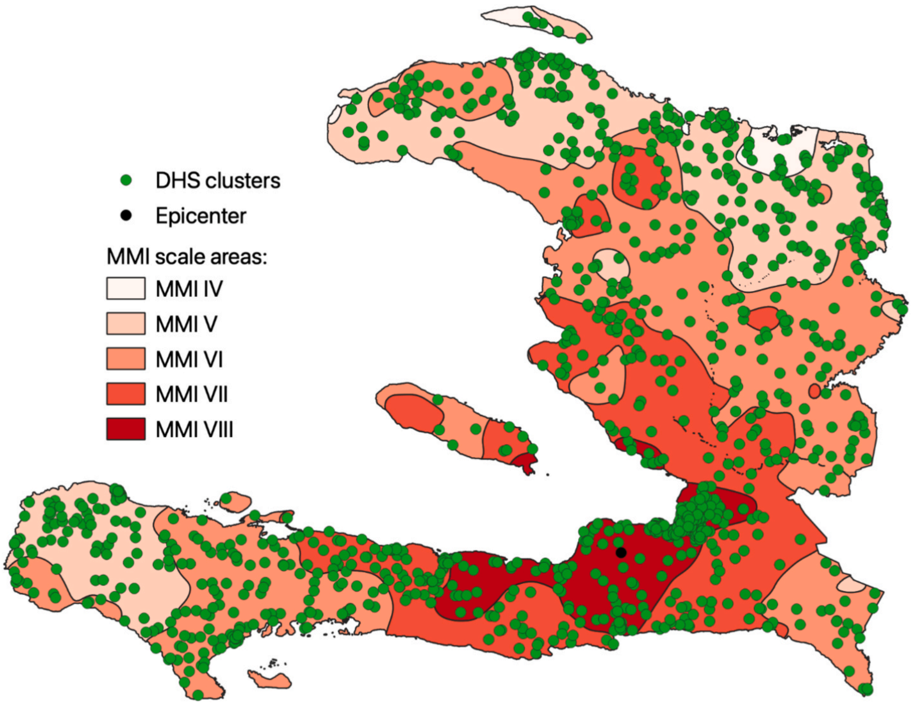

Fig. 2. Map of Haiti with DHS clusters, MMI areas, and epicenter created in QGIS with data from USGS (2017) and Haiti DHS 2005–06, 2012, and 2016–17.

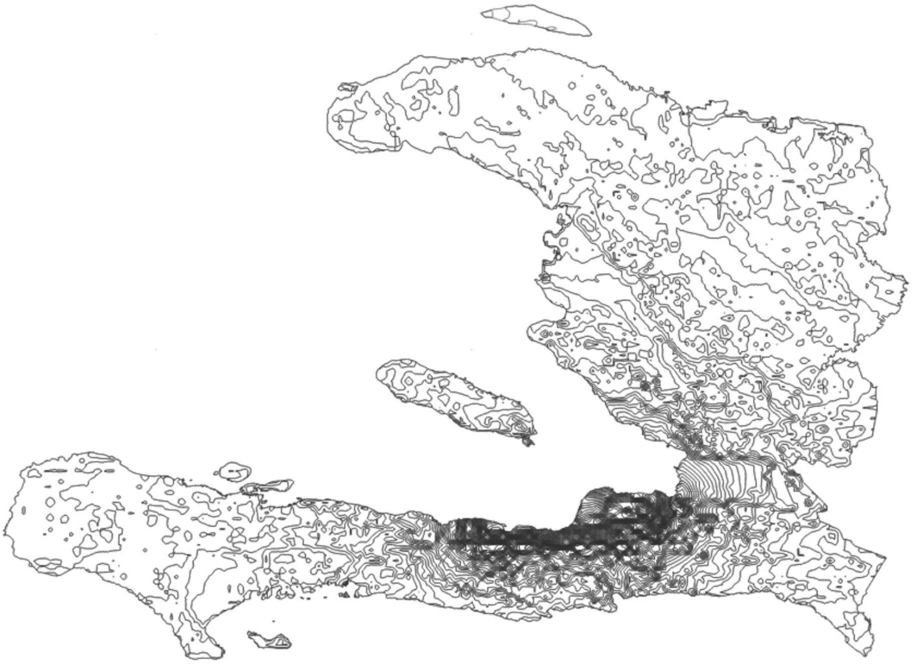

Fig. 3. Map of Haiti with PGA areas.

mothers who had lived eight years or more in current location at time of interview is slightly higher for the 2016–17 survey than for the 2005–06 survey, which could imply that people's movement patterns did not change drastically as a consequence of the earthquake (Table 3).

See Table 2, Table 3, and Table 4 for descriptive statistics.

3.4. Statistical analysis

The statistical analysis consists of a linear regression model with HAZ as the dependent variable to determine whether HAZ varies across birth year and across areas more or less affected by the earthquake. The linear regression models are illustrated by the equations,

$$y_{ij} = \alpha + \beta_1 birthyear_i + \beta_2 MMI_j + \beta_3 MMI_j{*}birthyear_i + \beta_k x_p + \varepsilon_{ij} \tag{1}$$

$$y_{ij} = \alpha + \beta_1 birth\,year_i + \beta_2 PGA_j + \beta_3 PGA_j{*}birth\,year_i + \beta_k x_p + \varepsilon_{ij} \tag{2}$$

The value of the outcome variable is y_{ij} for child i in MMI area j for the first equation and for child i in PGA area j for the second equation. For both equations, *birth year$_i$*, earthquake severity (*MMI$_j$* and *PGA$_j$*) and the interaction term with *birth year$_i$* and earthquake severity *(MMI$_j$* or *PGA$_j$*)

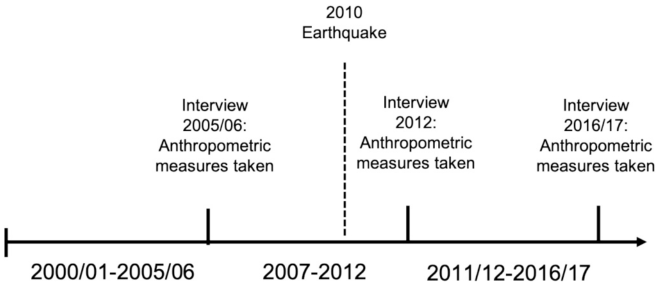

Fig. 4. Illustration of survey waves, birth years with anthropometric measures for each wave and year of earthquake.

Table 2
Descriptive statistics for children age five or younger across survey wave and MMI areas.

	MMI IV & V	MMI VI	MMI VII	MMI VIII
2005–06 Survey				
Age (mean)	2.4	2.3	2.3	2.4
Stunted	32.8 %	34.2 %	31.9 %	16.6 %
Urban	32.4 %	20.8 %	13.9 %	66.3 %
Maternal education				
No education	32.4 %	43.4 %	43.8 %	15.1 %
Primary education	49.2 %	40.3 %	39.7 %	37.3 %
Secondary/higher education	18.5 %	16.3 %	16.5 %	47.6 %
Female	47.8 %	51.4 %	52.8 %	53.2 %
Wealth				
Poorest	24.1 %	36.4 %	24.9 %	5.3 %
Poorer	27.9 %	26.2 %	36.9 %	2.6 %
Middle	22.9 %	22.8 %	21.1 %	9.1 %
Richer	18.3 %	10.8 %	13.2 %	37.8 %
Richest	6.9 %	3.8 %	4.0 %	45.2 %
Total children	875	637	526	424
2012 Survey				
Age at time of interview	2.3	2.3	2.3	2.2
Stunted	24.8 %	23.4 %	23.8 %	14.3 %
Urban	31.2 %	15.5 %	15.3 %	62.4 %
Maternal education				
No education	20.9 %	23.6 %	31.1 %	13.0 %
Primary education	49.3 %	49.3 %	38.3 %	36.9 %
Secondary/higher education	29.8 %	27.0 %	30.7 %	50.1 %
Female	49.8 %	49.2 %	49.9 %	47.5 %
Wealth				
Poorest	34.7 %	35.0 %	28.0 %	5.8 %
Poorer	20.5 %	33.3 %	30.6 %	7.9 %
Middle	16.6 %	16.2 %	18.1 %	26.5 %
Richer	16.9 %	10.3 %	15.8 %	33.0 %
Richest	11.3 %	5.2 %	7.6 %	26.8 %
Total children	1,131	1,210	619	970
2016–17 Survey				
Age at time of interview	2.4	2.4	2.5	2.5
Stunted	18.5 %	25.0 %	20.7 %	18.7 %
Urban	33.9 %	17.0 %	16.7 %	64.3 %
Maternal education				
No education	17.8 %	28.6 %	21.0 %	12.3 %
Primary education	43.7 %	39.8 %	39.4 %	31.8 %
Secondary/higher education	38.5 %	31.6 %	39.6 %	55.9 %
Female	51.2 %	50.7 %	48.9 %	48.7 %
Wealth				
Poorest	30.7 %	38.5 %	26.7 %	7.5 %
Poorer	21.4 %	28.3 %	22.3 %	11.3 %
Middle	18.6 %	19.4 %	23.5 %	23.1 %
Richer	18.7 %	8.4 %	17.9 %	28.5 %
Richest	10.7 %	5.4 %	9.6 %	29.7 %
Total children	1,751	1,866	1,056	910

*Weights applied for all numbers except total children.

are the independent variables. The interaction term is included to identify if the effects associated with birth cohorts differed across geographical areas with different earthquake intensity.

Table 3
Descriptive Statistics on survey specific variables per MMI: earthquake specific questions from 2012 survey at household level and women who have lived eight years or more in current location at time of interview for 2005–06 survey and 2016–17 survey.

Variable	MMI IV/V	MMI VI	MMI VII	MMI VIII
2012 (Total households: 12,943)				
Lived in current housing during earthquake**	78.6 %	79.3 %	75.8 %	60.9 %
Housing damaged during earthquake	15.5 %	22.3 %	39.5 %	59.0 %
Person killed during/after earthquake	0.9 %	1.6 %	1.2 %	5.1 %
One or more people wounded during earthquake	0.8 %	1.0 %	1.8 %	8.8 %
Death because of cholera after October 2010	1.4 %	2.2 %	1.1 %	0.3 %
Cholera survivor after October 2010	18.1 %	21.0 %	15.1 %	9.8 %
2005–06				
Living 8 years or more (Total children: 2,462)	60.2 %	74.5 %	72.7 %	52.3 %
2016–17				
Living 8 years or more (Total women: 5,583)	71.7 %	75.1 %	74.1 %	54.7 %

*Weights applied for all numbers. **Total number of households: 11,613.

Table 4
Percentage of stunted children and total children per annual birth cohorts from 2003 to 2017.

Birth year	Mean HAZ	(CI 95 %)	Stunted (%)	Total
Reference*	−1.4	(−1.5, −1.3)	30.6	869
2003	−1.5	(−1.7, −1,4)	35.8	455
2004	−1.5	(−1.6, −1.3)	35.6	523
2005	−0.8	(−0.9, −0.6)	18.0	562
2006	−0.7	(−1.1, −0.3)	13.2	53
2007	−1.1	(−1.2, −1.0)	19.2	416
2008	−1.3	(−1.4, −1.2)	28.2	733
2009	−1.3	(−1.4, −1.2)	27.5	727
2010	−1.2	(−1.3, −1.1)	27.4	849
2011	−0.5	(−0.6, −0.4)	12.8	969
2012	−0.9	(−0.9, −0.8)	18.1	1,257
2013	−1.1	(−1.2, −1.0)	22.8	986
2014	−1.3	(−1.4, −1.2)	31.2	1,112
2015	−1.1	(−1.2, −1.0)	24.5	1,092
2016	−0.4	(−0.5, −0.3)	11.4	1,209
2017	−0.5	(−0.8, −0.4)	9.8	163
Total children	−1.0	(−1.1, −1.0)	23.3	11,975

*Birth year 2000, 2001, 2002.

Control variables are illustrated with x_p in the equation. ε_{ij} is the error term. Model 1 is the baseline model without controls. Model 2 includes one control variable. The epicentre of the earthquake was close to the capital Port-au-Prince and the most severely impacted areas are therefore predominantly urban, so a binary control variable according to urban and rural place of residence is included as the first control variable. Finally, in model 3, two additional control variables are included. The second control variable is a categorical variable of maternal education (no education, primary, secondary/higher), since higher maternal education is associated with a lower chance of being undernourished and mothers in the most severely impacted areas have more education than mothers living outside this area (Table 2). The final control variable is a categorical variable of the ten administrative divisions (departments) and one camp (321 children of mothers located in camp in the 2012 survey). Multicollinearity among the control variables was assessed by applying the variance inflation factor (vif) command in Stata which showed a low degree of multicollinearity. Clustered standard errors at DHS cluster level are applied in all models. Analyses were conducted with the software Stata 16.1.

3.5. Sensitivity analysis

Two sensitivity analyses are applied. First, a control variable indicating total amount of aid in USD (divided by 100,000) distributed by region in 2010 and 2011 as reported by the World Bank Donor System and published by AidData[4] is included in Model 3. Most camps were located in Ouest, so respondents living in camps (identified in the 2012 survey) were given the same value as respondents in Ouest department. To avoid collinearity the control variable region is not included in the model.

Second, sensitivity analysis includes an additional control variable for model 3 capturing age in months at time of interview. This is the time when anthropometric measures were taken, and children within the same cohort and from the same survey wave could differ 12 months in age. Additionally, the 2012 cohort consists of children from both the 2012 survey (244) and from the 2016–17 survey (1,013) reflecting different ages at time of measurement. The continuous age variable in months accounts for the different vulnerabilities and protective factors to undernutrition within each cohort.

4. Results

As illustrated in Fig. 5, there is an increase in mean HAZ between the survey years 2005–06 and 2016–17. This illustrates an improvement at country level from 2005–06 onwards.

Table 5 shows the results from models 1–3, where the first is the baseline model, the second includes a control for place of residence (urban/rural), and the third includes controls for maternal education and administrative division. In model 1, the birth years show significant positive HAZ for children born close to the interview in 2005–06 located in MMI IV/V, followed by significant positive HAZ from birth year 2011 until 2017. Model 2 and model 3 show a similar pattern as for model 1, though no significant coefficients for 2006 and 2014 in model 3. Thus, there is no trend in HAZ in the birth year main effects for children located in MMI IV/V.

The results from the interaction of birth year variables and MMI areas show limited or no significant results for children born 2003 to 2010 across all MMI areas for all models; the only exception is MMI VIII in 2005. Thus, there were no differences in HAZ trends between the MMI areas before the earthquake. However, for children born in 2011 onwards the results show significant negative HAZ for MMI VIII in model 1, except for children born in 2013 and 2017. In model 2, there is a similar pattern with significant negative HAZ for children in MMI VIII except for 2013, 2015, and 2017. In model 3, with all three control variables, there are limited or no significant results for children born between 2003 and 2011, but also here a significant negative impact on HAZ for children born in 2012, 2014, and 2016 located in MMI VIII. This shows that the 2010 earthquake had a negative impact on children in MMI VIII relative to the other areas.

Table 6 shows the results for model 1–3 for PGA as a continuous measure of the earthquake exposure. As for model 1, the birth years show a significant positive HAZ for children born 2005 to 2008 and for those born 2010 to 2017. Model 2 shows a similar pattern as for model 1, while model 3 shows no significant coefficients for 2004, 2008, 2009, 2010, and 2014. Thus, only in model 3 there are no significant birth year main effects for children located in the immediate two years before the earthquake and the earthquake year 2010.

In the pre-earthquake years, the interaction of birth year variables and PGA show significant negative coefficients for children born in 2005 for all models, and for model 1 and 2 also for children born in 2008. After the earthquake, children born in 2010 onwards show a significant negative HAZ except for children born in 2013 for model 1 and model 2. This is a similar pattern as for the results observed in Table 5 for the MMI earthquake severity measure. When adding all three control variables in model 3, the pattern is also similar as for the MMI model 3 with negative significant result for children born in 2012, 2014 and 2016. The results show that the more severe earthquake impact in the areas where these children lived the lower the HAZ.

Fig. 6 illustrates the predicted values of HAZ for the interaction between birth year variables and MMI areas MMI IV/V (least affected and reference category) and MMI VIII (most affected) for model 3. There are indications of a parallel trend in the immediate years prior to the earthquake for the two areas. Between 2010 and 2011 the pre-earthquake difference between the predicted values vanishes, while after 2011 the gap changes in size and does not show a stable pattern. The values for MMI VIII show an improvement between 2010 and 2011, but a drop is observed from 2011 to 2014. Equally, for MMI IV/V, the predicted values of HAZ show an improvement immediately after the earthquake, with a following decline. In 2014 and 2016 the predicted values for MMI VIII are lower than for MMI IV/V.

4.1. Sensitivity analysis

Two sensitivity analysis were applied, the first controls for aid and the second adds a control with age in month at time of interview. First, the results remain stable when controlling for aid reported in the World Bank Donor System (Appendix, Table 1a and 1b). It is unlikely that these data capture the entire picture of international assistance in Haiti in 2010 and 2011, so it cannot be ruled out that international support, such as aid and remittances, had an impact on child undernutrition. Second, the last sensitivity analysis included age in months as a control to capture different vulnerabilities by age within each cohort (Appendix, Table 2a and 2b). Also here, the results remain stable.

5. Discussion and Conclusion

This paper investigated whether the Haiti 2010 earthquake affected child nutrition, measured through height-for-age, by comparing children in years before and after the earthquake across areas that were more or less impacted by the disaster. Overall, the results show that children born in many of the post-earthquake years located in severely impacted areas had significantly lower HAZ relative to children from less affected areas.

The results only show an impact in the years following the earthquake, which highlights the importance of critical and sensitive periods. The findings underline that the youngest children were more sensitive to exposure of the 2010 earthquake and the following humanitarian response. Although there is not a consistent statistically significant impact on children born in 2010, most of whom were in utero at the time of the earthquake, the results still reflect a significant impact on children who were in utero during the post-disaster years. This finding is in line with Barker's fetal origins hypothesis (Barker, 1995) and more recent literature on earthquake and birth outcomes after in utero exposures (Tan et al., 2009; Torche, 2011; Kim, Carruthers and Harris, 2017). The impact of the earthquake was not just immediate in the sense that it only affected children who experienced the event itself; it also seems to have affected children born as late as 2016. Thus, a major disaster such as the Haiti 2010 earthquake can generate changes in social, economic, political, and environmental conditions that last for years after the disaster.

The 2010 earthquake resulted in a comprehensive national and international humanitarian response, although this response has been criticised for lack of coordination and an unequal distribution of aid (Stumpenhorst, Stumpenhorst and Razum, 2011; Altay and Labonte, 2014; Hutson, Trzcinski and Kolbe, 2014; ACAPS, 2021). An unequal distribution of aid may have resulted in more assistance reaching those sub-populations that were less affected, and vice versa. The results

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[4] AidData: https://www.aiddata.org/ and https://geo.aiddata.org/#!/.

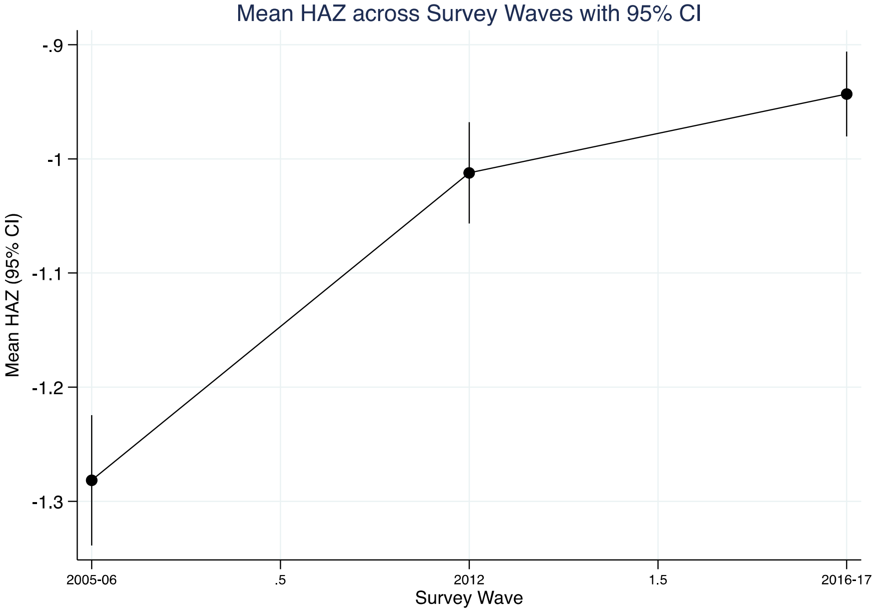

Fig. 5. Descriptive statistics of mean HAZ across survey year.

presented here reflect this possibility, with children located in the most affected areas experiencing significantly lower HAZ in the post-earthquake years relative to children from less affected areas. Controlling for 2010 and 2011 aid in the sensitivity analysis did not affect the results (Appendix Table 1a and 1b), suggesting that aid in these years had limited impact on child nutritional status measured through HAZ. Though, the aid variable does not capture the entire picture of incoming disaster relief, so whether the distribution of aid contributed to an improved or worsen situation in some areas is yet unclear. There is limited evidence that development aid, which is aid provided in non-emergency contexts and for non-emergency purposes, can generate measurable child health gains in general (Rustad, Rosvold and Buhaug, 2020). The results reflect challenges for children from the most affected areas when the aid transitioned into the development phase. A known challenge in disasters of this size is the transition or overlap between the provision of immediate humanitarian assistance and long-term development assistance, which is described as the humanitarian-development nexus (Stamnes, 2016; Strand, 2020). To ensure effective aid after major disasters, such as the 2010 earthquake in Haiti, it is of great importance to have well-coordinated, timely, and targeted responses and programmes that reach the intended population, and to ensure a smooth transition from humanitarian to development aid.

Another important factor that needs to be taken into consideration when interpreting the results is the post-earthquake cholera epidemic. The epidemic began with the first case of the disease in Haiti for a century in October 2010, and it then progressed rapidly (Luquero et al., 2016). The introduction of cholera into the Haitian population has resulted in at least 10,000 cholera deaths and almost 800,000 reported cases (Ivers, 2017). Infectious diseases such as diarrhoea are important determinants of childhood stunting (Black et al., 2013). Unfortunately, the available data do not allow for investigation of the potential impact of the cholera epidemic on child undernutrition after the 2010 earthquake. Two important elements of cholera vulnerability are access to health care and safe water (Ivers, 2017), both of which are likely to have been affected by the earthquake. Although the cholera epidemic affected all departments within 1 month (Luquero et al., 2016), the source of the outbreak was closer to areas less affected by the earthquake (MMI VI and MMI VII), which may have led to a stronger impact of the cholera epidemic in these areas than the most affected areas (see Table 3). Both the earthquake and cholera led to increased mortality among children (Kolbe et al., 2010; Luquero et al., 2016). If the most fragile and vulnerable children died because of the cholera outbreak, this mortality pattern could potentially help explain why children in less affected areas were better off than children in the most affected areas in the post-disaster years.

Two additional factors may have had an impact on the results. First, the earthquake most likely pushed families to migrate from the most affected areas to the least affected areas. If so, the impact on child nutrition in the most affected areas in the short-term might be less notable, since many of the most affected families may have migrated to less affected areas. However, the net flow (the difference between in and out population flows) into Port-au-Prince became positive 20 days after the earthquake, and by the end of the year, the population increase levelled off and stabilised (Lu, Bengtsson and Holme, 2012). The proportion of children who had lived eight years or more in the same location at time of interview did not differ between 2005–06 and 2016–17 (see Table 3). These data indicate that population movements because of the earthquake most likely had limited impact on the geographical MMI location of the children in the 2012 survey. However, because data on migration are missing it is not possible to be certain. Second, the most affected area, MMI VIII, differs greatly from the other areas in urban/rural settlement and socioeconomic indicators (Table 2). This area is predominantly urban, includes a higher number of educated mothers, and a higher share of wealthier households, which could potentially also reflect other geographical advantages. Such advantages could include access to vaccinations, health care, and clean water and sanitation, which are important determinants of childhood stunting (Black et al., 2013). Even so, this beneficial socioeconomic composition did not protect the children from the long-term consequences of the earthquake.

There are several limitations to this study. First, there is some inaccuracy in the locations of children according to the various MMI and PGA areas, for example due to geomasking. This means that some DHS clusters might be located in a lower intensity MMI or PGA than their actual location, while others might be located in a higher intensity MMI or PGA. The MMI analysis only captures four MMI areas, so there will be a small number of DHS clusters located close to the MMI borders that have an increased likelihood of being misplaced, but it cannot be ruled

Table 5
OLS regression models for HAZ on birth year and MMI areas with control variables.

		Mod. 1			Mod. 2			Mod.3		
Variable	**Category**	**Coeff.**	**CI (95 %)**		**Coeff.**	**CI (95 %)**		**Coeff.**	**CI (95 %)**	
Birth year[a]	2003	−0.178	(−0.419,	0.062)	−0.167	(−0.405,	0.070)	−0.202	(−0.437,	0.034)
	2004	−0.087	(−0.310,	0.136)	−0.083	(−0.305,	0.140)	−0.122	(−0.350,	0.106)
	2005	0.612***	(0.353,	0.871)	0.619***	(0.363,	0.875)	0.554***	(0.297,	0.810)
	2006	0.806*	(0.181,	1.431)	0.794*	(0.185,	1.402)	0.823	(0.225,	1.420)
	2007	0.157	(−0.130,	0.443)	0.187	(−0.089,	0.463)	0.136	(−0.126,	0.398)
	2008	0.041	(−0.212,	0.295)	0.061	(−0.185,	0.307)	−0.016	(−0.260,	0.228)
	2009	0.105	(−0.155,	0.365)	0.120	(−0.133,	0.373)	0.012	(−0.232,	0.256)
	2010	0.163	(−0.088,	0.413)	0.174	(−0.067,	0.415)	0.061	(−0.171,	0.293)
	2011	0.943***	(0.702,	1.184)	0.963***	(0.727,	1.199)	0.874***	(0.645,	1.103)
	2012	0.611***	(0.385,	0.836)	0.620***	(0.399,	0.841)	0.521***	(0.305,	0.736)
	2013	0.362**	(0.115,	0.609)	0.377**	(0.135,	0.619)	0.239*	(0.002,	0.477)
	2014	0.272*	(0.037,	0.506)	0.285*	(0.055,	0.515)	0.123	(−0.101,	0.347)
	2015	0.446***	(0.209,	0.683)	0.454***	(0.222,	0.686)	0.310**	(0.085,	0.534)
	2016	1.142***	(0.924,	1.361)	1.167***	(0.952,	1.383)	0.998***	(0.788,	1.207)
	2017	0.900***	(0.500,	1.300)	0.951***	(0.554,	1.347)	0.740***	(0.390,	1.089)
MMI	MMI IV/V	Ref.	–	–	Ref.	–	–	Ref.	–	–
	MMI VI	−0.101	(−0.365,	0.164)	−0.071	(−0.332,	0.190)	−0.092	(−0.353,	0.169)
	MMI VII	0.009	(−0.302,	0.320)	0.048	(−0.253,	0.349)	−0.013	(−0.324,	0.298)
	MMI VIII	0.575***	(0.319,	0.831)	0.481***	(0.229,	0.734)	0.377**	(0.096,	0.658)
2003 x MMI	2003 MMI IV/V	Ref.	–	–	Ref.	–	–	Ref.	–	–
	2003 MMI VI	−0.043	(−0.419,	0.332)	−0.058	(−0.430,	0.314)	−0.040	(−0.401,	0.322)
	2003 MMI VII	0.032	(−0.355,	0.418)	0.028	(−0.352,	0.407)	0.089	(−0.287,	0.466)
	2003 MMI VIII	0.241	(−0.166,	0.648)	0.218	(−0.191,	0.626)	0.246	(−0.155,	0.646)
2004 x MMI	2004 MMI IV/V	Ref.	–	–	Ref.	–	–	Ref.	–	–
	2004 MMI VI	0.121	(−0.241,	0.483)	0.117	(−0.242,	0.476)	0.125	(−0.233,	0.483)
	2004 MMI VII	0.203	(−0.182,	0.587)	0.178	(−0.203,	0.559)	0.222	(−0.160,	0.604)
	2004 MMI VIII	−0.112	(−0.473,	0.249)	−0.142	(−0.504,	0.221)	−0.099	(−0.458,	0.261)
2005 x MMI	2005 MMI IV/V	Ref.	–	–	Ref.	–	–	Ref.	–	–
	2005 MMI VI	0.362	(−0.034,	0.758)	0.355	(−0.039,	0.750)	0.371	(−0.029,	0.771)
	2005 MMI VII	0.104	(−0.326,	0.535)	0.099	(−0.322,	0.520)	0.166	(−0.261,	0.592)
	2005 MMI VIII	−0.550*	(−0.987,	−0.114)	−0.573*	(−1.008,	−0.138)	−0.499*	(−0.922,	−0.076)
2006 x MMI	2006 MMI IV/V	Ref.	–	–	Ref.	–	–	Ref.	–	–
	2006 MMI VI	−0.274	(−1.189,	0.641)	−0.280	(−1.194,	0.635)	−0.445	(−1.376,	0.486)
	2006 MMI VII	−0.019	(−1.167,	1.130)	−0.031	(−1.123,	1.060)	−0.144	(−1.257,	0.968)
	2006 MMI VIII	0.220	(−1.007,	1.447)	0.228	(−1.035,	1.490)	0.356	(−0.796,	1.507)
2007 x MMI	2007 MMI IV/V	Ref.	–	–	Ref.	–	–	Ref.	–	–
	2007 MMI VI	0.265	(−0.141,	0.671)	0.262	(−0.137,	0.661)	0.224	(−0.151,	0.599)
	2007 MMI VII	0.239	(−0.260,	0.737)	0.218	(−0.264,	0.701)	0.232	(−0.213,	0.678)
	2007 MMI VIII	−0.101	(−0.518,	0.317)	−0.117	(−0.529,	0.294)	0.049	(−0.338,	0.437)
2008 x MMI	2008 MMI IV/V	Ref.	–	–	Ref.	–	–	Ref.	–	–
	2008 MMI VI	0.183	(−0.187,	0.554)	0.190	(−0.173,	0.553)	0.186	(−0.165,	0.536)
	2008 MMI VII	0.296	(−0.160,	0.751)	0.296	(−0.143,	0.736)	0.318	(−0.104,	0.740)
	2008 MMI VIII	−0.219	(−0.598,	0.159)	−0.234	(−0.608,	0.141)	−0.044	(−0.411,	0.324)
2009 x MMI	2009 MMI IV/V	Ref.	–	–	Ref.	–	–	Ref.	–	–
	2009 MMI VI	−0.015	(−0.391,	0.361)	0.000	(−0.367,	0.367)	0.005	(−0.349,	0.358)
	2009 MMI VII	0.105	(−0.347,	0.556)	0.091	(−0.345,	0.527)	0.111	(−0.299,	0.521)
	2009 MMI VIII	−0.167	(−0.531,	0.197)	−0.168	(−0.532,	0.196)	−0.003	(−0.351,	0.345)
2010 x MMI	2010 MMI IV/V	Ref.	–	–	Ref.	–	–	Ref.	–	–
	2010 MMI VI	0.230	(−0.144,	0.604)	0.237	(−0.127,	0.601)	0.233	(−0.108,	0.573)
	2010 MMI VII	−0.068	(−0.485,	0.349)	−0.054	(−0.457,	0.349)	−0.027	(−0.405,	0.350)
	2010 MMI VIII	−0.369	(−0.763,	0.024)	−0.360	(−0.749,	0.030)	−0.172	(−0.530,	0.187)
2011 x MMI	2011 MMI IV/V	Ref.	–	–	Ref.	–	–	Ref.	–	–

(*continued on next page*)

Table 5 (*continued*)

Variable	Category	Mod. 1			Mod. 2			Mod.3		
		Coeff.	CI (95 %)		Coeff.	CI (95 %)		Coeff.	CI (95 %)	
	2011 MMI VI	0.121	(−0.249,	0.491)	0.127	(−0.238,	0.493)	0.058	(−0.287,	0.402)
	2011 MMI VII	0.064	(−0.371,	0.499)	0.057	(−0.368,	0.483)	0.069	(−0.335,	0.473)
	2011 MMI VIII	−0.355*	(−0.701,	−0.009)	−0.371*	(−0.711,	−0.030)	−0.209	(−0.549,	0.130)
2012 x MMI	2012 MMI IV/V	Ref.	–	–	Ref.	–	–	Ref.	–	–
	2012 MMI VI	0.001	(−0.334,	0.335)	0.008	(−0.320,	0.337)	0.009	(−0.303,	0.322)
	2012 MMI VII	0.096	(−0.308,	0.500)	0.096	(−0.296,	0.489)	0.086	(−0.286,	0.459)
	2012 MMI VIII	−0.482**	(−0.824,	−0.139)	−0.480**	(−0.821,	−0.139)	−0.409*	(−0.727,	−0.090)
2013 x MMI	2013 MMI IV/V	Ref.	–	–	Ref.	–	–	Ref.	–	–
	2013 MMI VI	−0.091	(−0.450,	0.268)	−0.081	(−0.434,	0.272)	−0.041	(−0.378,	0.296)
	2013 MMI VII	0.167	(−0.244,	0.579)	0.167	(−0.233,	0.568)	0.211	(−0.171,	0.592)
	2013 MMI VIII	−0.304	(−0.680,	0.072)	−0.301	(−0.677,	0.076)	−0.197	(−0.553,	0.159)
2014 x MMI	2014 MMI IV/V	Ref.	–	–	Ref.	–	–	Ref.	–	–
	2014 MMI VI	−0.226	(−0.567,	0.116)	−0.207	(−0.543,	0.129)	−0.189	(−0.507,	0.129)
	2014 MMI VII	0.003	(−0.417,	0.422)	0.010	(−0.399,	0.420)	0.042	(−0.346,	0.429)
	2014 MMI VIII	−0.556**	(−0.930,	−0.182)	−0.547**	(−0.911,	−0.183)	−0.446*	(−0.785,	−0.106)
2015 x MMI	2015 MMI IV/V	Ref.	–	–	Ref.	–	–	Ref.	–	–
	2015 MMI VI	−0.052	(−0.407,	0.302)	−0.038	(−0.388,	0.313)	−0.040	(−0.370,	0.291)
	2015 MMI VII	−0.107	(−0.515,	0.300)	−0.114	(−0.510,	0.282)	−0.092	(−0.473,	0.288)
	2015 MMI VIII	−0.408*	(−0.810,	−0.006)	−0.386	(−0.791,	0.020)	−0.286	(−0.663,	0.092)
2016 x MMI	2016 MMI IV/V	Ref.	–	–	Ref.	–	–	Ref.	–	–
	2016 MMI VI	0.107	(−0.220,	0.433)	0.100	(−0.224,	0.425)	0.099	(−0.213,	0.410)
	2016 MMI VII	−0.050	(−0.445,	0.345)	−0.050	(−0.438,	0.339)	−0.017	(−0.387,	0.353)
	2016 MMI VIII	−0.783***	(−1.177,	−0.389)	−0.793***	(−1.186,	−0.400)	−0.710***	(−1.084,	−0.337)
2017 x MMI	2017 MMI IV/V	Ref.	–	–	Ref.	–	–	Ref.	–	–
	2017 MMI VI	−0.012	(−0.586,	0.561)	−0.046	(−0.616,	0.523)	−0.041	(−0.592,	0.509)
	2017 MMI VII	−0.100	(−0.745,	0.545)	−0.148	(−0.801,	0.506)	−0.156	(−0.764,	0.452)
	2017 MMI VIII	−0.121	(−0.834,	0.593)	−0.018	(−0.740,	0.705)	0.092	(−0.562,	0.746)
Place of residence	Rural				Ref.	–	–	Ref.	–	–
	Urban				0.273***	(0.201,	0.345)	0.128***	(0.060,	0.197)
Education	No education							Ref.	–	–
	Primary							0.267***	(0.192,	0.342)
	Secondary/higher							0.638***	(0.557,	0.719)
Division	Oest							Ref.	–	–
	Sud-Est							0.062	(−0.094,	0.217)
	Nord							−0.033	(−0.216,	0.150)
	Nord-Est							−0.010	(−0.193,	0.174)
	Artibonite							0.078	(−0.077,	0.233)
	Centre							−0.039	(−0.201,	0.124)
	Sud							0.209*	(0.040,	0.379)
	Grand’anse							0.004	(−0.180,	0.188)
	Nord-Ouest							0.181*	(0.006,	0.356)
	Nippes							0.183*	(0.029,	0.336)
	Camp							−0.264*	(−0.468,	−0.060)
Total sample		11,975			11,975			11,975		
Prob > F		0.0000			0.0000			0.0000		
R-squared		0.0734			0.0800			0.1107		

Significance codes: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

[a] Reference category for birth year is children born in 2000, 2001, and 2002.

Table 6
OLS regression models for HAZ on birth year and PGA as a continuous earthquake measure.

		Mod. 1			Mod. 2			Mod.3		
Variable	**Category**	**Coeff.**	**CI (95 %)**		**Coeff.**	**CI (95 %)**		**Coeff.**	**CI (95 %)**	
Birth year[a]	2003	−0.190	(−0.382,	0.002)	−0.184	(−0.372,	0.006)	−0.206*	(−0.393,	−0.019)
	2004	0.017	(−0.168,	0.203)	0.016	(−0.169,	0.200)	−0.015	(−0.201,	0.170)
	2005	0.885***	(0.672,	1.097)	0.890***	(0.680,	1.100)	0.832***	(0.620,	1.044)
	2006	0.652*	(0.098,	1.205)	0.633*	(0.084,	1.182)	0.572*	(0.021,	1.123)
	2007	0.349**	(0.133,	0.565)	0.367**	(0.156,	0.578)	0.279**	(0.082,	0.476)
	2008	0.233*	(0.035,	0.431)	0.249*	(0.057,	0.442)	0.146	(−0.040,	0.331)
	2009	0.130	(−0.064,	0.325)	0.141	(−0.049,	0.331)	0.020	(−0.163,	0.202)
	2010	0.293**	(0.096,	0.490)	0.308**	(0.116,	0.499)	0.167	(−0.014,	0.347)
	2011	1.049***	(0.854,	1.245)	1.065***	(0.874,	1.257)	0.932***	(0.748,	1.116)
	2012	0.696***	(0.518,	0.873)	0.706***	(0.532,	0.879)	0.591***	(0.425,	0.757)
	2013	0.391***	(0.199,	0.582)	0.412***	(0.224,	0.599)	0.281**	(0.100,	0.462)
	2014	0.247*	(0.059,	0.435)	0.264**	(0.081,	0.447)	0.100	(−0.075,	0.275)
	2015	0.474***	(0.286,	0.662)	0.484***	(0.299,	0.668)	0.322***	(0.147,	0.498)
	2016	1.296***	(1.120,	1.473)	1.320***	(1.145,	1.496)	1.141***	(0.970,	1.311)
	2017	0.866***	(0.564,	1.169)	0.880***	(0.575,	1.184)	0.661***	(0.367,	0.955)
PGA		0.882***	(0.545,	1.218)	0.727***	(0.394,	1.060)	0.556**	(0.197,	0.915)
Cohort x PGA	2003 x PGA	0.260	(−0.300,	0.819)	0.235	(−0.323,	0.794)	0.281	(−0.277,	0.839)
	2004 x PGA	−0.237	(−0.711,	0.236)	−0.261	(−0.736,	0.215)	−0.215	(−0.685,	0.254)
	2005 x PGA	−1.089**	(−1.551,	−0.467)	−1.104***	(−1.724,	−0.485)	−0.994**	(−1.600,	−0.387)
	2006 x PGA	0.503	(−1.551,	2.557)	0.517	(−1.592,	2.625)	0.737	(−1.214,	2.687)
	2007 x PGA	−0.345	(−0.874,	0.184)	−0.336	(−0.851,	0.179)	−0.068	(−0.548,	0.412)
	2008 x PGA	−0.537*	(−1.036,	−0.038)	−0.533*	(−1.024,	−0.042)	−0.241	(−0.711,	0.229)
	2009 x PGA	−0.194	(−0.633,	0.245)	−0.173	(−0.615,	0.270)	0.055	(−0.373,	0.484)
	2010 x PGA	−0.584*	(−1.084,	−0.084)	−0.574*	(−1.073,	−0.075)	−0.275	(−0.741,	0.190)
	2011 x PGA	−0.549*	(−1.011,	−0.087)	−0.557*	(−1.006,	−0.107)	−0.294	(−0.754,	0.166)
	2012 x PGA	−0.689**	(−1.138,	−0.241)	−0.680**	(−1.126,	−0.234)	−0.564**	(−0.984,	−0.145)
	2013 x PGA	−0.360	(−0.866,	0.146)	−0.367	(−0.875,	0.141)	−0.223	(−0.712,	0.266)
	2014 x PGA	−0.654*	(−1.178,	−0.131)	−0.631*	(−1.135,	−0.126)	−0.487*	(−0.960,	−0.014)
	2015 x PGA	−0.654*	(−1.166,	−0.142)	−0.620*	(−1.133,	−0.106)	−0.454	(−0.936,	0.029)
	2016 x PGA	−1.211***	(−1.739,	−0.684)	−1.219***	(−1.752,	−0.686)	−1.084***	(−1.605,	−0.562)
	2017 x PGA	−0.146	(−1.090,	0.799)	0.015	(−0.957,	0.987)	0.109	(−0.819	1.037)
Place of residence	Rural				Ref.	–	–	Ref.	–	–
	Urban				0.276***	(0.205,	0.346)	0.135***	(0.066,	0.204)
Education	No education							Ref.	–	–
	Primary							0.269***	(0.195,	0.344)
	Secondary/higher							0.642***	(0.561,	0.723)
Division	Oest							Ref.	–	–
	Sud-Est							0.071	(−0.083,	0.224)
	Nord							−0.037	(−0.204,	0.130)
	Nord-Est							−0.024	(−0.184,	0.137)
	Artibonite							0.066	(−0.093,	0.225)
	Centre							−0.077	(−0.235,	0.081)
	Sud							0.161	(0.002,	0.324)
	Grand'anse							−0.013	(−0.181,	0.156)
	Nord-Ouest							0.170*	(0.011,	0.330)
	Nippes							0.170*	(0.022,	0.317)
	Camp							−0.273**	(−0.474,	−0.072)
Total sample		11,975			11,975			11,975		
Prob > F		0.0000			0.0000			0.0000		
R-squared		0.0693			0.0765			0.1077		

Significance codes: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

[a] Reference category for birth year is children born in 2000, 2001, and 2002.

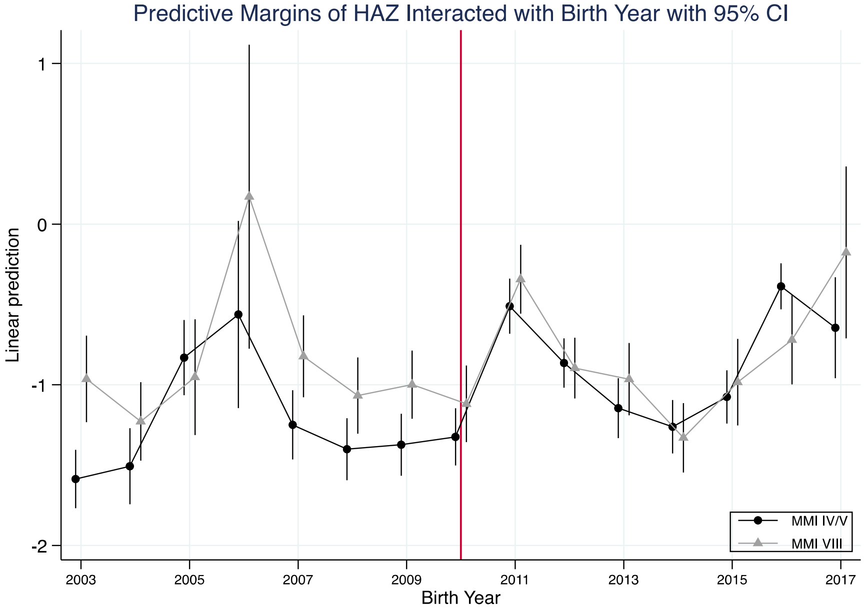

Fig. 6. Predictive margins of HAZ, MMI (IV/V and VIII) interacted with birth year with 95% CI.

out that this creates estimation errors. For the PGA analysis the measure is more fine-grained and less differences between the different PGA areas. Further, the borders between the different earthquake impacted areas do not reflect a clear and distinct difference, but rather a gradual spectrum of earthquake severity. Migration may also have affected the results, since populations are likely to move from severely impacted areas to less impacted areas. Second, the MMI is considered a good indicator of severity for the emergency phase, but it requires good reports and observations by people on the ground. According to a report by Eberhard and colleagues (2010), there were no seismographic stations in Haiti during the main earthquake or the aftershocks. The ShakeMaps used in this paper were last updated in 2017 (USGS, 2017). Uncertainties in the MMI measurement are likely, but it should nevertheless capture the varying geographical impact of the earthquake. The PGA measure complements the MMI measure and the results from both earthquake severity measures contributes to the overall picture. Third, the anthropometric measures were taken at the time of the interview for children under age five, meaning that a possible temporary deprivation of child nutrition, such as wasting, cannot be fully captured in the design of this study. Chronic nutritional deprivation, measured through height-for-age, is therefore a better measure of undernutrition, although catch-up growth among the oldest children could still have occurred before the anthropometric measures were taken. Fourth, the earthquake and cholera epidemic led to increased child mortality, which may have contributed to a selection bias. It is likely that the most fragile and vulnerable children died, while stronger and healthier children survived. If so, the results will most likely be biased, whereas a more severe earthquake-impact on child nutrition might have been observed if the weaker children had also survived. Fifth, in the design used here, birth cohort is used as a proxy for time in the analysis. However, this approach has limitations. For example, the 2012 birth cohort has HAZ measurements from both 2012 and 2016–17 survey rounds. Given the strong association between child age and HAZ in contexts of high food insecurity and malnutrition, this could introduce bias. Finally, Haiti is a fragile state frequently affected by both political and civil unrest, as well as natural hazard related disasters. There might therefore be other confounding factors relevant for the Haitian context that could have affected the results.

The association between humanitarian and development assistance and child nutrition should be of interest in future research investigating child nutrition in disaster contexts. It would also be of interest to better understand how such assistance can mitigate the potential negative outcomes on health and human capital accumulation. Additionally, whether the long-term implications for child nutrition can be generalised to other low-income settings should be considered. How to address these long-term implications for child nutrition will require a better understanding of the potential differences in the determinants of chronic child undernutrition between more and less affected areas. Another important question for future research is how disasters potentially can lead to outcomes later in life, using a life course perspective, which would require health data collection of the adult population in areas affected by such disasters. Finally, the results imply that there may have been an improvement in HAZ for children located in less impacted areas. This has also been indicated in studies and reports at the national level (Ayoya et al., 2013; Evans and Bassani, 2018; Institut Haïtien de l'Enfance (IHE) and ICF, 2018). Whether there has been an improvement or stagnation in less impacted areas after the 2010 earthquake remains for future research to explore.

This paper investigated variations in child nutrition (height-for-age z-scores) across birth cohorts and earthquake severity. The results show that the more severe the earthquake impact the lower the HAZ for children born in the years following the earthquake. The national and international humanitarian assistance may have protected children's nutritional status in less affected areas and possibly also reduced the negative impact in the most affected areas. The challenges faced by a poor country in the recovery phase after a disaster of this size may be overwhelming. To reduce the impact on child undernutrition in such contexts, it is of great importance to ensure a strong focus on programmes promoting maternal and child health, not only in the immediate aftermath but also in the long term.

CRediT authorship contribution statement

Hilde Orderud: Writing – review & editing, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix

Table 1a
Model 3 for HAZ on birth year and MMI areas without control variable region and with control variable World Bank aid.

		Model 3		
Variable	**Category**	**Coeff.**	**CI (95 %)**	
Birth year[1]	2003	−0.198	(−0.433,	0.038)
	2004	−0.131	(−0.358,	0.096)
	2005	0.542***	(0.285,	0.799)
	2006	0.790**	(0.198,	1.382)
	2007	0.125	(−0.136,	0.386)
	2008	−0.024	(−0.264,	0.217)
	2009	−0.003	(−0.244	0.239)
	2010	0.053	(−0.177,	0.283)
	2011	0.860***	(0.629,	1.091)
	2012	0.510***	(0.295,	0.726)
	2013	0.239*	(0.005,	0.474)
	2014	0.114	(−0.109,	0.338)
	2015	0.303**	(0.078,	0.528)
	2016	0.990***	(0.779,	1.200)
	2017	0.749***	(0.387,	1.111)
MMI	MMI IV/V	Ref.	–	–
	MMI VI	−0.064	(−0.316,	0.187)
	MMI VII	0.034	(−0.262,	0.329)
	MMI VIII	0.415**	(0.155,	0.675)
2003 x MMI	2003 MMI IV/V	Ref.	–	–
	2003 MMI VI	−0.041	(−0.405,	0.323)
	2003 MMI VII	0.085	(−0.292,	0.461)
	2003 MMI VIII	0.237	(−0.162,	0.637)
2004 x MMI	2004 MMI IV/V	Ref.	–	–
	2004 MMI VI	0.123	(−0.234,	0.480)
	2004 MMI VII	0.229	(−0.152,	0.610)
	2004 MMI VIII	−0.092	(−0.450,	0.266)
2005 x MMI	2005 MMI IV/V	Ref.	–	–
	2005 MMI VI	0.385	(−0.014,	0.784)
	2005 MMI VII	0.184	(−0.240,	0.609)
	2005 MMI VIII	−0.488*	(−0.912,	−0.065)
2006 x MMI	2006 MMI IV/V	Ref.	–	–
	2006 MMI VI	−0.320	(−1.245,	0.605)
	2006 MMI VII	−0.062	(−1.192,	1.067)
	2006 MMI VIII	0.420	(−0.736,	1.577)
2007 x MMI	2007 MMI IV/V	Ref.	–	–
	2007 MMI VI	0.221	(−0.158,	0.601)
	2007 MMI VII	0.255	(−0.195,	0.706)
	2007 MMI VIII	−0.038	(−0.425,	0.348)
2008 x MMI	2008 MMI IV/V	Ref.	–	–
	2008 MMI VI	0.174	(−0.178,	0.526)
	2008 MMI VII	0.326	(−0.097,	0.749)
	2008 MMI VIII	−0.121	(−0.478,	0.235)
2009 x MMI	2009 MMI IV/V	Ref.	–	–
	2009 MMI VI	0.019	(−0.335,	0.373)
	2009 MMI VII	0.130	(−0.283,	0.543)
	2009 MMI VIII	−0.072	(−0.410,	0.265)
2010 x MMI	2010 MMI IV/V	Ref.	–	–
	2010 MMI VI	0.241	(−0.105,	0.587)
	2010 MMI VII	−0.019	(−0.398,	0.359)
	2010 MMI VIII	−0.257	(−0.621,	0.106)
2011 x MMI	2011 MMI IV/V	Ref.	–	–
	2011 MMI VI	0.080	(−0.274,	0.433)
	2011 MMI VII	0.088	(−0.320,	0.497)
	2011 MMI VIII	−0.298	(−0.624,	0.028)
2012 x MMI	2012 MMI IV/V	Ref.	–	–
	2012 MMI VI	0.008	(−0.310,	0.325)
	2012 MMI VII	0.074	(−0.305,	0.454)
	2012 MMI VIII	−0.414*	(−0.732,	−0.096)
2013 x MMI	2013 MMI IV/V	Ref.	–	–
	2013 MMI VI	−0.037	(−0.376,	0.301)
	2013 MMI VII	0.195	(−0.189,	0.580)
	2013 MMI VIII	−0.201	(−0.554,	0.153)
2014 x MMI	2014 MMI IV/V	Ref.	–	–

(*continued on next page*)

Table 1a (*continued*)

		Model 3		
Variable	**Category**	**Coeff.**	**CI (95 %)**	
	2014 MMI VI	−0.189	(−0.513,	0.135)
	2014 MMI VII	0.037	(−0.354,	0.428)
	2014 MMI VIII	−0.442*	(−0.780,	−0.103)
2015 x MMI	2015 MMI IV/V	Ref.	–	–
	2015 MMI VI	−0.038	(−0.373,	0.297)
	2015 MMI VII	−0.095	(−0.478,	0.288)
	2015 MMI VIII	−0.283	(−0.660,	0.094)
2016 x MMI	2016 MMI IV/V	Ref.	–	–
	2016 MMI VI	0.108	(−0.205,	0.422)
	2016 MMI VII	−0.015	(−0.387,	0.357)
	2016 MMI VIII	−0.708***	(−1.081,	−0.334)
2017 x MMI	2017 MMI IV/V	Ref.	–	–
	2017 MMI VI	−0.017	(−0.577,	0.542)
	2017 MMI VII	−0.144	(−0.760,	0.473)
	2017 MMI VIII	0.084	(−0.573,	0.741)
Place of residence	Rural	Ref.	–	–
		0.114**	(0.046,	0.183)
Education	No education	Ref.	–	–
	Primary	0.279***	(0.204,	0.354)
	Secondary/ higher	0.661***	(0.580,	0.742)
World Bank aid	USD per region	−21.534	(−53.587,	10.519)
Total sample		11,975		
Prob > F		0.0000		
R-squared		0.1070		

Significance codes: $*p < 0.05$; $**p < 0.01$; $***p < 0.001$.

[1] Reference category for birth year is children born in 2000, 2001, and 2002.

Table 1b

Model 3 for HAZ on birth year and PGA areas without control variable region and with control variable World Bank aid.

		Model 3		
Variable	**Category**	**Coeff.**	**CI (95 %)**	
Birth year[1]	2003	−0.202*	(−0.390,	−0.014)
	2004	−0.026	(−0.211,	0.160)
	2005	0.829***	(0.617,	1.041)
	2006	0.582*	(0.037,	1.127)
	2007	0.285**	(0.084,	0.486)
	2008	0.146	(−0.041,	0.332)
	2009	0.027	(−0.155	0.210)
	2010	0.175	(−0.008,	0.358)
	2011	0.940***	(0.753,	1.127)
	2012	0.582***	(0.414,	0.750)
	2013	0.281**	(0.099,	0.463)
	2014	0.090	(−0.087,	0.268)
	2015	0.319***	(0.142,	0.496)
	2016	1.138***	(0.966,	1.309)
	2017	0.689***	(0.392,	0.986)
PGA		0.593**	(0.246,	0.940)
Cohort x PGA	2003 x PGA	0.267	(−0.293,	0.827)
	2004 x PGA	−0.200	(−0.669,	0.269)
	2005 x PGA	−0.989**	(−1.595,	−0.383)
	2006 x PGA	0.821	(−1.153,	2.795)
	2007 x PGA	−0.215	(−0.706,	0.277)
	2008 x PGA	−0.359	(−0.828,	0.109)
	2009 x PGA	−0.072	(−0.486,	0.342)
	2010 x PGA	−0.412	(−0.890,	0.066)
	2011 x PGA	−0.438	(−0.877,	−0.000)
	2012 x PGA	−0.587**	(−1.010,	−0.164)
	2013 x PGA	−0.235	(−0.724,	0.253)
	2014 x PGA	−0.489*	(−0.964,	−0.014)
	2015 x PGA	−0.462	(−0.944,	0.021)
	2016 x PGA	−1.090**	(−1.612,	−0.567)
	2017 x PGA	0.079	(−0.851,	1.010)
Place of residence	Rural	Ref.	–	–
		0.112**	(0.045,	0.179)
Education	No education	Ref.	–	–
	Primary	0.280***	(0.205,	0.356)
	Secondary/ higher	0.664***	(0.583,	0.745)
World Bank aid	USD per region	−13.092	(−43.846,	17.662)
Total sample		11,975		
Prob > F		0.0000		
R-squared		0.1038		

Significance codes: $*p < 0.05$; $**p < 0.01$; $***p < 0.001$.

[1] Reference category for birth year is children born in 2000, 2001, and 2002.

Table 2a

Model 3 for HAZ on birth year and MMI areas with additional control variable age in months at time of interview.

		Mod.3		
Variable	**Category**	**Coeff.**	**CI (95 %)**	
Birth year[1]	2003	−0.442***	(−0.689,	0.195)
	2004	−0.540***	(−0.792,	−0.288)
	2005	−0.026	(−0.319,	0.268)
	2006	0.153	(−0.460,	0.766)
	2007	0.243	(−0.022,	0.507)
	2008	−0.039	(−0.283,	0.206)
	2009	−0.182	(−0.429,	0.064)
	2010	−0.301*	(−0.545,	−0.057)
	2011	0.341*	(0.079,	0.603)
	2012	0.453***	(0.238,	0.668)
	2013	0.167	(−0.071,	0.406)
	2014	−0.107	(−0.340,	0.125)
	2015	−0.098	(−0.346,	0.150)
	2016	0.430**	(0.178,	0.682)
	2017	0.078	(−0.311,	0.466)
MMI	MMI IV/V	Ref.	–	–
	MMI VI	−0.093	(−0.354,	0.168)
	MMI VII	−0.029	(−0.339,	0.281)
	MMI VIII	0.370*	(0.087,	0.653)
2003 x MMI	2003 MMI IV/V	Ref.	–	–
	2003 MMI VI	−0.044	(−0.409,	0.321)
	2003 MMI VII	0.097	(−0.283,	0.478)
	2003 MMI VIII	0.245	(−0.156,	0.646)
2004 x MMI	2004 MMI IV/V	Ref.	–	–
	2004 MMI VI	0.131	(−0.226,	0.488)
	2004 MMI VII	0.238	(−0.142,	0.618)
	2004 MMI VIII	−0.093	(−0.452,	0.266)
2005 x MMI	2005 MMI IV/V	Ref.	–	–
	2005 MMI VI	0.371	(−0.028,	0.771)
	2005 MMI VII	0.189	(−0.237,	0.616)
	2005 MMI VIII	−0.481*	(−0.905,	−0.057)
2006 x MMI	2006 MMI IV/V	Ref.	–	–
	2006 MMI VI	−0.429	(−1.352,	0.495)
	2006 MMI VII	−0.116	(−1.225,	0.993)
	2006 MMI VIII	0.373	(−0.773,	1.520)
2007 x MMI	2007 MMI IV/V	Ref.	–	–
	2007 MMI VI	0.224	(−0.151,	0.600)
	2007 MMI VII	0.244	(−0.202,	0.689)
	2007 MMI VIII	0.055	(−0.334,	0.443)
2008 x MMI	2008 MMI IV/V	Ref.	–	–
	2008 MMI VI	0.191	(−0.161,	0.543)
	2008 MMI VII	0.328	(−0.096,	0.751)
	2008 MMI VIII	−0.055	(−0.423,	0.314)
2009 x MMI	2009 MMI IV/V	Ref.	–	–
	2009 MMI VI	−0.001	(−0.355,	0.352)
	2009 MMI VII	0.110	(−0.299,	0.519)
	2009 MMI VIII	−0.022	(−0.372,	0.328)
2010 x MMI	2010 MMI IV/V	Ref.	–	–
	2010 MMI VI	0.228	(−0.112,	0.568)
	2010 MMI VII	−0.023	(−0.398,	0.353)
	2010 MMI VIII	−0.182	(−0.541,	0.177)
2011 x MMI	2011 MMI IV/V	Ref.	–	–
	2011 MMI VI	0.055	(−0.289,	0.398)
	2011 MMI VII	0.075	(−0.329,	0.479)
	2011 MMI VIII	−0.206	(−0.546,	0.134)
2012 x MMI	2012 MMI IV/V	Ref.	–	–
	2012 MMI VI	0.020	(−0.290,	0.331)
	2012 MMI VII	0.132	(−0.235,	0.500)
	2012 MMI VIII	−0.355*	(−0.679,	−0.032)
2013 x MMI	2013 MMI IV/V	Ref.	–	–
	2013 MMI VI	−0.034	(−0.371,	0.303)
	2013 MMI VII	0.234	(−0.147,	0.615)
	2013 MMI VIII	−0.196	(−0.554,	0.161)
2014 x MMI	2014 MMI IV/V	Ref.	–	–
	2014 MMI VI	−0.191	(−0.509,	0.128)
	2014 MMI VII	0.060	(−0.328,	0.447)
	2014 MMI VIII	−0.458**	(−0.799,	−0.118)
2015 x MMI	2015 MMI IV/V	Ref.	–	–
	2015 MMI VI	−0.035	(−0.364,	0.295)
	2015 MMI VII	−0.069	(−0.448,	0.310)
	2015 MMI VIII	−0.288	(−0.667,	0.091)
2016 x MMI	2016 MMI IV/V	Ref.	–	–
	2016 MMI VI	0.098	(−0.214,	0.409)

(*continued on next page*)

Table 2a (*continued*)

		Mod.3		
	2016 MMI VII	0.003	(−0.366,	0.372)
	2016 MMI VIII	−0.712***	(−1.087,	−0.336)
2017 x MMI	2017 MMI IV/V	Ref.	–	–
	2017 MMI VI	−0.039	(−0.590,	0.512)
	2017 MMI VII	−0.137	(−0.746,	0.473)
	2017 MMI VIII	0.105	(−0.550,	0.761)
Place of residence	Rural	Ref.	–	–
	Urban	0.132***	(0.063,	0.200)
Education	No education	Ref.	–	–
	Primary	0.252***	(0.177,	0.327)
	Secondary/ higher	0.626***	(0.545,	0.707)
Division	Oest	Ref.	–	–
	Sud-Est	0.064	(−0.093,	0.221)
	Nord	−0.038	(−0.222,	0.146)
	Nord-Est	−0.009	(−0.193,	0.175)
	Artibonite	0.081	(−0.074,	0.237)
	Centre	−0.052	(−0.214,	0.109)
	Sud	0.220*	(0.051,	0.388)
	Grand'anse	0.022	(−0.163,	0.208)
	Nord-Ouest	0.184*	(0.008,	0.360)
	Nippes	0.198*	(0.044,	0.352)
	Camp	−0.304**	(−0.510,	−0.098)
Age (months)		−0.014***	(−0.018	−0.011)
Total sample		11,975		
Prob > F		0.0000		
R-squared		0.1166		

Significance codes: *p < 0.05; **p < 0.01; ***p < 0.001.

[1] Reference categories for birth year is 2000, 2001, and 2002.

Table 2b

Model 3 for HAZ on birth year and PGA areas with additional control variable age in months at time of interview.

		Mod.3		
Variable	**Category**	**Coeff.**	**CI (95 %)**	
Birth year[1]	2003	−0.446***	(−0.643,	−0.248)
	2004	−0.428***	(−0.638,	−0.217)
	2005	0.258*	(0.005,	0.510)
	2006	−0.087	(−0.652,	0.479)
	2007	0.387***	(0.186,	0.588)
	2008	0.130	(−0.056,	0.315)
	2009	−0.173	(−0.358,	0.011)
	2010	−0.193	(−0.391,	0.621)
	2011	0.402***	(0.183,	0.698)
	2012	0.533***	(0.369,	0.400)
	2013	0.218*	(0.036,	0.059)
	2014	−0.125	(−0.309,	0.126)
	2015	−0.078	(−0.281,	0.150)
	2016	0.579***	(0.363,	0.796)
	2017	0.005	(−0.335,	0.344)
PGA		0.548**	(0.187,	0.910)
Cohort x PGA	2003 x PGA	0.282	(−0.276,	0.840)
	2004 x PGA	−0.210	(−0.678,	0.259)
	2005 x PGA	−0.972**	(−1.582,	−0.362)
	2006 x PGA	0.756	(−1.186,	2.697)
	2007 x PGA	−0.059	(−0.539,	0.421)
	2008 x PGA	−0.262	(−0.732,	0.208)
	2009 x PGA	0.029	(−0.402,	0.461)
	2010 x PGA	−0.292	(−0.758,	0.174)
	2011 x PGA	−0.296	(−0.756,	0.164)
	2012 x PGA	−0.508*	(−0.939,	−0.077)
	2013 x PGA	−0.229	(−0.721,	0.263)
	2014 x PGA	−0.506*	(−0.980,	−0.118)
	2015 x PGA	−0.455	(−0.938,	0.091)
	2016 x PGA	−1.090***	(−1.615,	−0.336)
	2017 x PGA	0.124	(−0.806,	0.761)
Place of residence	Rural	Ref.	–	–
	Urban	0.138***	(0.069,	0.207)
Education	No education	Ref.	–	–
	Primary	0.255***	(0.180,	0.330)
	Secondary/ higher	0.630***	(0.549,	0.712)
Division	Oest	Ref.	–	–
	Sud-Est	0.073	(−0.081,	0.226)
	Nord	−0.043	(−0.211,	0.124)
	Nord-Est	−0.024	(−0.186,	0.137)

(*continued on next page*)

Table 2b (*continued*)

		Mod.3		
	Artibonite	0.068	(−0.091,	0.228)
	Centre	−0.091	(−0.248,	0.067)
	Sud	0.170*	(0.007,	0.333)
	Grand'anse	0.005	(−0.164,	0.174)
	Nord-Ouest	0.172*	(0.011,	0.333)
	Nippes	0.184*	(0.036,	0.332)
	Camp	−0.312**	(−0.514,	−0.110)
Age (months)		−0.014***	(−0.017	−0.011)
Total sample		11,975		
Prob > F		0.0000		
R-squared		0.1135		

Significance codes: *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

[1] Reference categories for birth year is 2000, 2001, and 2002.

Data availability

This paper used publicly available data from Demographic and Health Surveys (DHS) and geocoded data on the 2010 Haiti earthquake from United States Geological Survey (USGS).

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