Lasting Impact on Health from Natural Disasters, Potential Mechanisms and Mitigating Effects

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Abstract

Exposure to extreme shocks in early life is found to have lasting impact in adulthood. Exploiting the variation in exposure measured by age and intensity of earthquake, we evaluate the impact of a 7.7 M_W earthquake in Gujarat, India, on the health stock of children who were in utero or below three years. Using the India Human Development Survey (IHDS-1) data (2004-05) and earthquake intensity data, we find, an affected girl child to be shorter by at least 2.5 cm at the age of 3-6 years. The earthquake seems to have destroyed the household infrastructures and health facilities, affecting the expecting mothers and newborn children. The households using services to meet nutritional needs of children and pregnant women seem to be least affected. Our findings recommend faster reconstruction activities and highlight the importance of universal healthcare and nutritional delivery services to mitigate the impacts of early-life shocks.

(JEL Codes: I1, I3, J1, O2)

Key words: Earthquake, child health, height, ZHFA, Shock, India.

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1. Introduction

According to the estimates of the United Nations (2000), every year approximately 30 million infants in developing countries are observed to have symptoms of impaired growth at the time of birth due to inadequate nutrition in the fetal life. Children who are unable to meet their nutritional requirements in the initial “critical” and “sensitive” period (Knudsen, 2004) of life remain malnourished in later life. Studies have established that lack of nourishment and poor health in the early childhood result in worse human capital outcomes not only in the short run but also in the long run (Victora et al., 2008; Morgane et al., 1993). Poor infant health increases the risk of being prone to infectious diseases or sustained bad health in the childhood (Oreopoulos et al., 2008) as well as in the adulthood (Blackwell et al., 2001; Haas, 2007).

A large number of studies have used the variation in the shocks such as drought (Dinkelman, 2016; Hoddinott and Kinsey, 2001; Jensen, 2000; Maccini and Yang, 2009), famine (Chen and Zhou, 2007; Dercon and Porter 2014; Gorgens et al., 2012), flood (Del Ninno and Lundberg, 2005), epidemic (Almond, 2006; Almond and Mazumder, 2005; Kelly, 2011; Lin and Liu, 2014), and war (Alderman et al., 2006) to evaluate the impact on heath due to in-utero or early childhood exposure to shocks. In the recent time, researchers (Caruso and Miller, 2015; Finlay 2009; Fukuda et al. 1998; Gignoux and Menéndez, 2016; Nandi et al. 2017; Nobles et al. 2015; Tan et al., 2009; Tempesta et al., 2013; Thamarapani, 2021) have used earthquake as a shock which brings an exogenous source of variation in terms of its exposure. Negligible likelihood of prediction of such event creates a unique opportunity to evaluate its impact on the health outcomes of the children who are in-utero or in early childhood at the time of the earthquake.

Among the immediate term impacts, the comparison of neonates born before and after the 2008 Wenchuan earthquake reveals significantly lower birthweight and Apgar scores[3], high ratio of low birthweight children and high rate of premature births for post-earthquake cohort (Tan et al., 2009). In a series of papers, authors have found increased incidence of metabolic syndrome and disruptive nocturnal behaviors and deteriorated sleep quality in the individuals affected by the 2009 L'Aquila Earthquake (Tempesta et al., 2013). Using the National Family Health Survey (NFHS) data of India, Datar et al. (2013) estimate the immediate impact of shocks arising from a few small and moderate natural disasters and found evidence of stunting, wasting along with deficits in immunization coverage immediately after the disasters.

Several studies have established mixed impact of earthquake on fertility affecting through the channel of mortality shocks (Finlay, 2009, in three different countries – Gujarat of India in 2001, North-West Frontier of Pakistan in 2005 and Izmit of Turkey in 1999; Fukuda et al., 1998, for 1995 Kobe earthquake; Nandi et al., 2017, for Gujarat earthquake in 2001; Nobles et al., 2015, for 2004 Indian Ocean tsunami in Indonesia). However, literature analyzing the impact of early life shock from earthquake or tsunami on later life health (Andrabi et al. 2021; Thamarapani, 2021), education (Caruso and Miller, 2015), crime (Hombrados, 2020), and welfare (Gignoux and Menéndez, 2016) is nascent.

Andrabi et al. (2021) find that the children of Pakistan have accumulated a large height deficit, when they faced an earthquake shock under age 3, and have accumulated deficits in academic tests when they faced the shock at age 3-11. They also find evidence of mother's education working as a mitigating factor. We add on to this strand of literature by estimating the

[3] The Apgar score, reported at one and five minutes post birth, is a criterion used to evaluate the health of a newborn child based on five indexes – color, heart rate, reflex irritability, muscle tone and respiratory effort (American Academy of Pediatrics, 2006).

impact of 2001 Gujarat (India) earthquake on long run health outcomes of children measured by the stature. However, our primary contribution is the investigation of the potential mechanisms followed by recommendations for public policies, while the latter is substantiated through potential channels of mitigation.

Therefore, our objective in this study is three-fold. One, we begin with evaluating the long run impact of this major shock on the health stock of the surviving children who were in utero or under the age of three years at the time of earthquake. Two, we investigate the potential mechanisms through which the earthquake leaves behind a persistent negative impact. We are able to produce supportive evidence that both the destruction of public infrastructures in large scale, as well as nutritional deficiencies of the mothers during the crucial period are the potential reasons behind long term negative impacts. Three, we follow up our suggested mechanisms to check if the access to the related essential services could work as mitigating channels. Hence, we explore if the households using the Integrated Child Development Scheme (ICDS) are able to mitigate the impact of the disaster. ICDS is a multi-dimensional scheme, accessible nationwide, which intends to provide a combination of six services such as supplementary nutrition, pre-school education, immunization, health check-up, nutrition and health education, and referral services for children aged 0-6-year-old, adolescent girls, pregnant women and nursing mothers (MoWCD, 2017). Dhamija and Sen (2020) find that having access to the ICDS during the early years of life has been able to produce a strong positive impact on the health stock of children in the later life.

Among the existing studies that analyzed the impact of such a disaster on the health stocks of the surviving children in later lives[4], our contribution is the detailed analysis of the potential

[4] See Almond and Currie (2011), for a detailed analysis of the literature closest to our work, that is, the impact of early life or in-utero shock on later life outcomes.

mechanisms and establishing the channels for mitigation. The work closest to ours is that of Andrabi et al. (2021), which suggests mother's education as a channel for mitigation. While parents' education cannot be targeted as a corrective action in the immediate term, the access to healthcare infrastructures are more viable recourse as found in our work. Taking care of nutrition needs through village health care centers like ICDS is found to mitigate the impact and that should be of interest to policy makers in the immediate term.

We particularly focus on stature as outcome, as child height is considered to be an important indicator of nutritional status. It has been found that long run implications of poor childhood health can be best captured by an indicator such as height (Strauss and Thomas, 1998). Height being the output of various inputs, a combination of both genotype and phenotype influences play significant role in the nutritional health in-utero, at the time of birth or infancy (Martorell and Habicht, 1986). It has the potential of depicting the state of overall growth in the health of the child. Moreover, nutritional insults in terms of shorter height delays school enrollment, reduces cognitive ability in the young as well as in the later age, and lowers schooling attainment and lifetime earnings (Bossavie et al., 2021; Case and Paxson, 2008a; Case and Paxson, 2008b; Strauss and Thomas, 1998; Vogl, 2014).

In terms of the destruction caused due to an earthquake, one cannot claim that the damages caused to households are limited to any specific criterion. It is possible that households located near the epicenter of the earthquake face more destruction than the others. This generates another source of variation in terms of intensity of exposure, which also helps us to estimate the impact based on intensity. On average, we find that an increase in earthquake intensity by one unit (measured by Modified Mercalli Intensities or MMI, as explained later) seems to cause 2.54 cm lower height and 0.47 standard deviations lower ZHFA among the affected girls. In other words, an increase in earthquake intensity by one standard deviation (measured by MMI) seems to cause 0.07 standard deviation lower height and 0.39 standard deviations lower ZHFA among the affected girls. Additionally, a girl child belonging to younger cohort in severely affected region seems to be shorter by about 0.11 standard deviation (or 3 cm) than their unaffected counterparts. Our estimates are robust to different specifications.

In order to understand the potential mechanisms, we investigate the impact of earthquake on anti-natal investments, household infrastructures and village level health infrastructures. Specifically, we find that women who gave birth post-earthquake and belong to severely affected region had 5.8 percent lower likelihood of receiving any antenatal health worker visit, 0.38 lesser number of antenatal visits, and 6.7 percent lower likelihood of receiving iron and folic tablets during the last pregnancy as compared to their counterparts. In addition to this, the likelihood of individuals having a drinking water facility at home post-earthquake is 0.15 percent lower as compared to their unaffected counterparts. Moreover, village level regression analysis indicates that one unit increase in the earthquake intensity is associated with a reduction of the number of trained and untrained Dai[5] in the village by 0.61 and 0.36 respectively. The households using services targeted to meet nutritional needs of children and pregnant women seem to be the least affected. These findings highlight the importance of universal healthcare and nutritional delivery services in developing countries that can help to mitigate the long term impact of shocks caused by natural disasters.

The rest of the paper is organized as follows. Section 2 discusses the severity of the Gujarat earthquake. Section 3 elaborates the data used in the work. Section 4 explains identification

[5] Dai is a form of skilled healthcare worker in the villages or a midwife.

mechanism. Section 5 discusses the findings, potential mechanisms, and the mitigating effects of the ICDS. Section 6 concludes the discussion.

2. The Gujarat Earthquake

In 2001, the morning of 26th January brought an unfortunate disaster for the state of Gujarat when an extremely powerful earthquake measuring 7.7 M_W[6] shook the whole state at 8:46 A.M., local time. Its epicenter was traced at the Chaubari located in the north of Bhachau, about 250 km west of Ahmedabad and a depth of 25 km (GSDMA, 2002). More than 500 aftershocks of smaller magnitudes were felt after the main shock wave (Negishi et al., 2002).

According to government data, approximately 28 million individuals were affected by the destruction not only due to loss of physical capital but also due to loss of human capital in 21 out of 25 districts in Gujarat (Mishra, 2004). Out of these 21 affected districts, 6 districts namely Kutch, Jamnagar, Surendranagar, Rajkot, Patan and Ahmedabad were severely affected (Lahiri et al., 2001; GSDMA, 2002). Most of the health infrastructures were badly damaged which further escalated the severity of the problem especially on the vulnerable groups such as women and children (GSDMA, 2002). Around 442 villages from these severely affected districts had more than 70 percent of the houses destroyed due to earthquake (Mishra, 2004). Approximately 1.2 million houses had been damaged or destructed due to earthquake (GSDMA, 2002), while more than 20,000 individuals died and 1,66,000 were injured. More than 50% of the individuals who died were of the working age. Analysis based on the loss to Medium and Small scale industries and other labor market opportunities led to an estimated unemployment of approximately 0.488

[6] Based on US Geological Survey's estimate.

million persons. 'Memorandum on the Earthquake Damage in Gujarat[7] estimated a loss of about Rs 144.54 billion (equivalent to 1.94 billion dollars approximately) (Lahiri et al., 2001). In addition to this, economic loss of around 1.3 billion dollars was estimated by the Government of India (Hough et al., 2002). The teams responsible for assessment of the loss were more worried about the social costs of being homeless, mental trauma, poor physical health and reduced earning opportunities that are more difficult to recover. Recovery and reconstruction of the public and private assets were estimated to cost around 1.1 million dollars (GSDMA, 2002).

3. Data

We use first round of the India Human Development Survey (IHDS-1, 2005) data collected by joint research exercise of the University of Maryland and the National Council of Applied Economic Research (NCAER), New Delhi in 2004-05. It is multi-topic panel survey which covered 41,554 households spread over 1,503 villages and 971 urban blocks in 385 districts, across 33 states and union territories in India. This wide coverage makes this data set representative at the national, state and district level. This survey captures information related to health, education, employment, economic status, marriage, fertility, gender relations, and social capital for every household. It collects anthropometric information such as height and weight data of children under age 6, 8-11 years old, and ever-married women aged 15-49 years old at the time of survey.[8] We

[7] Submitted to the Government of India February 17, 2001.
[8] Appendix section I explains the reasons behind our choice of IHDS data in more detail.

calculate the Z score for height for age (ZHFA) using the British 1990 Growth Charts. It allows us to find standardized values of height for a cohort of children aged 0-23 years old[9].

In order to explore potential mechanisms behind the long run negative impact, we also use the District Level Household Surveys (DLHS) data of India. The Government of India started the District Level Household Surveys (DLHS) to assess the reproductive and child health indicators at the district level. The research exercise to carry out these surveys was delegated to the International Institute for Population Sciences. To date, periodic exercise of DLHS cross-sectional surveys have been completed four times (DLHS-1 in 1998-99, DLHS-2 in 2002-04, DLHS-3 in 2007-08 and DLHS-4 in 2012-13). In order to assess the impact of Gujarat earthquake on the prenatal investments, we specifically use the first two cross sectional rounds of DLHS. Household surveys in DLHS-1 and DLHS-2 are taken from 5,29,817 households (in 504 districts) and 6,20,107 households (in 593 districts) respectively.

The fieldworks for both DLHS-1 and DLHS-2 were done in two phases. The first phase of DLHS-1 was conducted in 1998 and the second phase was conducted in 1999 (IIPS, 2001). In DLHS-2, first phase was carried out in 2002 except for some districts of Bihar and Jharkhand, where the field work was extended to 2003. The second phase was carried out in 2004, except for some districts of Bihar and Jharkhand, that were covered in 2005 (IIPS, 2006). We do not use the second phase of DLHS-2 as there was a gap of three years between the earthquake (2001) and the second phase of DLHS-2 (2004). It helps us to avoid the possibility of the reconstruction of the health facilities three years post-earthquake as this may contaminate our results. We aim to cover those surveyed women who gave birth in the last two years. Therefore, for the study of the potential

[9] While the reason behind using the British Growth Chart instead of the more common WHO growth chart is explained in appendix section II, the supplementary table S9 presents estimates using WHO growth chart (with much smaller sample) as well, and our findings do not change.

mechanisms, we restrict the sample for those women who reported to give birth from 1997 to 1999 in DLHS-1, and from 2001 to 2002 in DLHS-2.

4. Conceptual Framework and Identification Strategy

Out of 25 districts in Gujarat in the year 2001[10], six were severely affected by the earthquake. According to Mishra (2004), more than 99 percent of the death toll was reported in the six severely affected districts (Figure A1). 15 other districts faced some damages of milder manner. Remaining four districts were not reported to be affected. However, IHDS-1 surveyed all the six severely affected districts, only 10 out of the 15 marginally affected districts and only one out of four unaffected districts in Gujarat. Therefore, our final sample of Gujarat gets restricted to a total of 17 districts.

4.1. Identification Using Difference in Difference

Our initial plan is to restrict the treatment group to six severely affected districts, and to compare them with the 10 marginally affected districts, with the premise that severely affected districts should face worse health outcomes as compared to the marginally affected ones. In order to distinguish these 10 districts from the only one unaffected Narmada district, we call the former as 'marginally affected' districts in Figure A1. However, in order to increase the sample size of the control group and to make it stronger with 'true' control who were not affected by the earthquake, we also include the other surveyed districts of the neighboring states of Maharashtra, Rajasthan and Madhya Pradesh in the control group, along with the unaffected Narmada district of Gujarat. The first level of difference is therefore, calculated across space, that is, among same

[10] Some districts bifurcated later, makes a current total of 33 districts in Gujarat in the year 2021.

age-cohorts belonging to six districts of Gujarat, with the 10 marginally affected districts and one unaffected district of Gujarat, plus all surveyed districts of Maharashtra, Rajasthan and Madhya Pradesh as listed in appendix table A1.

Since lack of nourishment for children in-utero or in the age group of 0-3-year can bring disastrous outcomes in the later life, we aim to restrict our treated group to the children born from 1998 to 2001, aged 3-6 years during 2004-05. The data collection for IHDS-1 was done from November 2004 to October 2005, with most of it being done in 2005. We restrict our treated group to those children whose age is reported as 4 or 5 in the survey year 2005 and whose age is reported as 3-5 in the survey year 2004.[11] With an objective of restricting our treated group to the children born in 2001 or before, we include only those children in the sample who report to be 4 or 5 year old in survey year 2005.[12] However, our results are robust to inclusion of children whose age is reported as 3 in the survey year 2005[13]. Moreover, to ensure that all individuals from our treated group have been truly exposed to the earthquake, we limit the sample to females in households, who have been in the same place at least for last 10 years.[14] Figure 1 explains the construction of treatment and control cohort.

[11] Anthropometric information for 6-year-old children was not collected in the survey, due to which inclusion of 6 years old cohort in the analysis is not possible.

[12] In order to understand the logic behind this selection, let us take an example: If the child is born in January 2001 then her completed age in survey year 2004 is reported as 3. In survey year 2005, it is reported as 4 if date of survey is on or after the birth date or else it is reported as 3. In such a scenario we should also include children whose age is reported as 3 in the survey year 2005. But inclusion of these cases will bring the possibility of children being included in the sample whose age is reported as 3 in July 2005 and born in June 2002.

[13] Results are not presented in this paper, but available with authors on request.

[14] Our findings do not change if we relax this sample restriction of residing in same place for last ten years. See appendix table A3 and table A4.

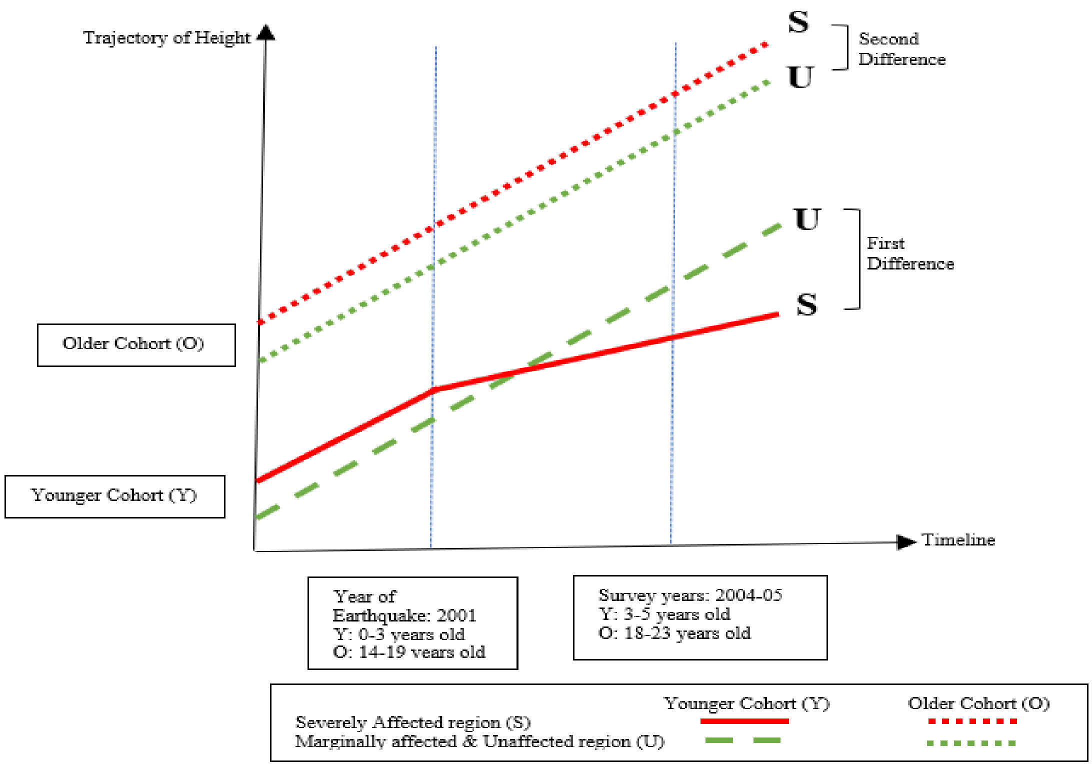

Figure 1: Schematic representation of trends in heights of children in treated and control group in different regions of Gujarat.

One may wonder why we choose to study two cohorts, knowing that *ex ante*, one expects not to observe a difference between young adults in treated and control regions as they are in the last stage of physical development. However, our double difference strategy helps to alleviate the concerns related to pre-treatment differences in health outcomes of children in the severely affected region and other region[15]. In order to control for pre-treatment differences between the earthquake-affected and unaffected regions, we need a counterfactual group who are unlikely to

[15] We also provide the estimates following the most straightforward approach by focusing only on children that are between 0-3 years old and compare the outcomes between affected and non-affected regions. The supplementary table S8 provides the magnitude of the effect of earthquake on 0-3 year male cohort. However, our preferred specification is not this one, as we believe the difference in difference estimation strategy can potentially address the concerns related to pre-treatment differences in health outcomes of children in the severely affected region and other region.

be affected by the earthquake in a way the outcomes of the treated cohort should be. Therefore, the second level of difference across time includes cohorts aged 18 to 23 years at the time of survey. By choosing this as the counterfactual cohort we ensure that youngest child in this cohort could be 14 year old at the time of earthquake. It is important to note that this cohort has already crossed the crucial age where malnutrition due to shock was expected to reduce growth. Moreover, the fact that puberty in females are complete by the age of 17 (Marcell, 2007), encourages us to choose 18 as the lowest age for the counterfactual cohort. So, we assume that this cohort is unlikely to get affected by the earthquake and will help in differencing out pre-treatment differences in the affected and unaffected regions.

Since anthropometric information for the elder group is collected only from the ever-married women, our analysis is restricted to female cohort for height and ZHFA. However, ZHFA could not be calculated for the individuals elder than 23 years due to unavailable reference data. Therefore, in all our primary specifications, our counterfactual cohort gets restricted to 18-23 years old in the survey year. However, the information on heights being available for the cohort up to 49 years, as we check the specification with 18-36 being the counterfactual, our estimates for height remain similar in magnitude[16]. For the analysis using the double difference strategy, and for the robustness checks, we restrict our sample to the individuals surveyed in four states Gujarat, Maharashtra, Rajasthan and Madhya Pradesh as listed in Table A1. For falsification tests, we also include the districts of the Bihar, Chhattisgarh and Uttar Pradesh in the analysis[17].

[16] Estimates are available with authors on request.
[17] See appendix figure A2 for the map of neighboring states used in one specification of control group, and other state used for falsification exercise.

Table 1: Unconditional Means of health outcomes by cohort and regions.

	Actual Experiment		Controlled Experiment
	(1)	(2)	(3)
VARIABLES	Height (in cm)	ZHFA in [-6,6]	Height (in cm)
Diff-in-diff (Y-O)	-5.21*	-0.35	-0.99
	(2.79)	(0.33)	(1.25)
Observations	2,146	2,057	8,205
R-squared	0.90	0.03	0.02
Older Cohort (O)			
Marginally affected & Unaffected region (U)	151.10	-2.07	151.12
Severely Affected region (S)	153.97	-1.54	154.99
Diff (S – U)	2.87**	0.53***	3.87***
	(1.18)	(0.17)	(0.43)
Younger Cohort (Y)			
Marginally affected & Unaffected region (U)	95.53	-1.60	151.09
Severely Affected region (S)	93.19	-1.41	153.97
Diff (S – U)	-2.34	0.19	2.88
	(2.53)	(0.28)	(1.18)

Data Source: IHDS 1.
Full sample of 98 districts including control district of neighboring states.
Robust standard errors are clustered at the district-age level. *** p<0.01, ** p<0.05, * p<0.1

In the actual experiment, younger cohort consists of females who were in-utero or under the age of 3 in 2001. Older cohort consists of females aged 14–19 years old at the time of earthquake in 2001. In the controlled experiment, younger cohort consists of 14-19 years old females, and older cohort consists of 20-45 years old females.

This identification strategy is based on the comparisons of both the height and ZHFA outcomes of females belonging to same cohort in severely affected versus other districts. We try to elaborate this in table 1, which has the unconditional means of health outcomes of different cohorts in different regions. In *Actual Experiment*, we compare the health outcomes of the *Older Cohort* females (14 to 19 year old at the time of earthquake) unlikely to be affected by the earthquake of 2001, to the *Younger Cohort* females directly affected being in-utero or under the age of 3 years during the earthquake. These comparisons are also made in both the *treated* and *control* regions.

We find that older cohort females belonging to the severely affected (*treated)* region may have both higher height and lower negative ZHFA as compared to those who belong to the *control* region. This may indicate better health outcomes for the older cohort in the severely affected region as compared to marginally affected and unaffected region. But the younger cohort that is expected to be affected due to earthquake has marginally lower height, indicating poor health outcomes among them in the severely affected regions. Under the assumption that health outcomes in the absence of earthquake would have been systematically indifferent in both the regions, we can interpret the difference in these differences as the effect of the earthquake on the health outcomes. Table 1 indicates that the unconditional average height seem to be 5.21 cm lower for younger cohort in the severely affected region, but we do not get statistically significant difference in ZHFA.

In order to test the implications of our assumption, we conduct a controlled experiment for height by comparing the means of health outcomes of two cohorts whom we expect to remain unaffected by the earthquake. We choose 18 to 23 years old and 24 to 49 years old (that are, 14 to 19 years, and 20 to 45 years old at the time of earthquake in 2001) women for this purpose. In column (3), we find that the unconditional double difference of mean height is not significant. This result provides supportive evidence that, our estimates are not influenced by any systematic differences in the two regions. Under the assumption that conditional on a host of observables and district-specific or time variant unobservable, differences across different cohorts in each of the outcomes would be similar between severely affected - *treated* districts and unaffected or marginally affected - *control* districts in the absence of the earthquake, we estimate the following equation in our first specification:

$$H_{ihjt} = \beta(Younger\ Cohort_i * Severely\ Affected\ Region_j) + \delta_t + \alpha_{jt} + \gamma_{sy} + \mu X_h + \varepsilon_{ihjt} \quad (1)$$

Where H_{ihjt} is the health outcomes measured by height (or ZHFA in alternative specification) for the individual i who belongs to household h in district j and birth year t[18]. *Younger Cohort*$_i$ is a dummy variable indicating whether the individual was in-utero or under age of three at the time of earthquake (=1). $Severely\ Affected\ Region_j$ is a dummy variable indicating the individual belonging to one of the six severely affected districts. We include birth-year fixed effects δ_t to account for unobservable time-variant changes that might have happened at both regions, which could also affect the health outcomes. α_{jt}, capturing the time-trend across districts, controls for the unobserved time-variant differences among districts which could cause differential developmental outcomes irrespective of the earthquake. All our estimates include survey-year fixed effects denoted by γ_{sy}. $\boldsymbol{X}_h$ controls for other household-specific covariates such as ethnicity, religion, and residence status, that may also affect the health outcomes of the children.[19] ε_{ihjt} is the error term with usual assumptions. Descriptive statistics about the background characteristics of individuals disaggregated by the region are provided in Table 2.

Table 2: Difference in means between severely and marginally affected districts of Gujarat

Means of Variable	Severely affected	Marginally affected	Overall	Difference	Standard Error
Height	129.419	127.857	128.572	1.562	3.62
ZHFA#	-1.503	-1.835	-1.687	0.332*	0.18
Younger Cohort	0.397	0.429	0.414	-0.032	0.06
Intensity	8.018	7.542	7.721	0.476	0.35
Age	14.529	13.950	14.215	0.579	0.97
Dependent Ratio	35.999	37.619	36.877	-1.620	2.35
Wealth Index	13.993	14.404	14.215	-0.411	0.61
Income source: agriculture or allied	0.301	0.280	0.290	0.022	0.05

[18] Throughout the analysis, age in years is used as a proxy for birth year due to large number of missing observations in the later.
[19] For robustness check, we also include education of the household head, dependent ratio, wealth index measured by the number of assets, primary source of income, sources of drinking water, and toilet facility in an additional specification.

Income source: agri wage labor	0.140	0.193	0.168	-0.053	0.04
Income source: non-agri wage labor	0.169	0.130	0.148	0.039	0.04
Income source: independent/petty shop	0.074	0.099	0.088	-0.026	0.03
Income source: business/salary/pension	0.301	0.292	0.296	0.010	0.05
Income source: others	0.015	0.006	0.010	0.008	0.01
Household Head's Education	4.051	6.124	5.175	-2.073***	0.54
Ethnicity: BC	0.596	0.441	0.512	0.155***	0.06
Ethnicity: SC	0.103	0.118	0.111	-0.015	0.04
Ethnicity: ST	0.000	0.081	0.044	-0.081***	0.02
Ethnicity: OC	0.301	0.360	0.333	-0.059	0.05
Religion: Hindu	0.882	0.857	0.869	0.025	0.04
Drinking water: Piped	0.610	0.609	0.609	0.002	0.06
Drinking water source: Tube well	0.059	0.093	0.077	-0.034	0.03
Drinking water source: Hand pump	0.081	0.155	0.121	-0.074**	0.04
Drinking water source: Other	0.250	0.143	0.192	0.107**	0.05
Defecation: Open fields	0.404	0.497	0.455	-0.093	0.06
Residence status: Urban	0.368	0.323	0.343	0.045	0.06
% villages in district: medical facility	54.550	80.974	68.874	-26.420***	2.02
% villages in district: paved roads	80.476	87.654	84.367	-7.178***	1.28
% of rural population in district	53.346	64.811	59.561	-11.460***	2.13
Sex Ratio in district	922.154	918.217	920.020	3.937	3.39
Observations	136	161	297	297	

Data Source: IHDS 1
*** p<0.01, ** p<0.05, * p<0.1
#ZHFA (in range [-6,6]) is available for only 124 individuals in severely affected districts and 154 individuals in marginally affected districts.

Since inference based on the clustered standard errors may be misleading if the number of clusters is less (Roodman et al., 2018), throughout all our regression estimates, we cluster the standard errors at the district-age level. However, our results remain qualitatively unchanged even after clustering the standard errors at the district level.[20]

4.2. Identification Using Earthquake Intensity as a Primary Evidence

The above-mentioned identification strategy may suffer from a few potential concerns. First, it is possible that some other shocks with potentials of affecting health outcomes may have

[20] See tables S3-S7 in supplementary materials for these robustness tests. However, the presence of spatial correlation in outcome as well as the main variable of interest may increase the likelihood of Type I error if it remains unaccounted for in the regression model (Colella et al., 2019). Arbitrary correlation regression based on the Stata command ‘acreg’ can give us the corrected standard errors after accounting for spatial correlation. But, we need the latitude, longitude, and bilateral distances between the observations to use this program. Unfortunately, IHDS data does not provide the household-level geocodes, in the absence of which, we could not use this Stata command to complete this robustness check.

occurred in one of the regions during the same time, causing treated and control districts to have different health outcomes irrespective of the earthquake. This is difficult to address in the above difference in difference framework using cross-section data. Second, the limited sample on unaffected districts (counterfactuals) persuades us to consider the moderately affected districts as counterfactuals as well. This has the potential of generating bias in our estimates. Even though we try to address that concern using districts from other neighboring states as counterfactual as well, but it is difficult to establish that those would be true controls. Hence the Difference in Difference strategy explained earlier requires validity of much stronger assumptions. Third, the above strategy treats all the districts in severely affected region uniformly. However, the intensity of earthquake is higher closer to the epicenter and reduces with the distance further away from the epicenter.

Therefore, in order to ensure that the observed health effects in the severely affected regions are due to the earthquake, our primary specification is a different model, where we use another variant of treatment capturing intensity of the earthquake data from Hough et al., (2002). Due to scarcity of instrumental recordings of the intensity at various locations, Hough et al., (2002) have used the extensive news articles on print media and electronic media in the United States and India, along with internet-based sources, to assign the Modified Mercalli Intensities (MMIs) at various locations. Based on the severity of ground shaking and destruction, these MMIs were assigned (for details please see Hough et al., 2002). MMIs are interpreted as point data. Hough et al., (2002) show that these intensities were inversely related to the distance from the epicenter. We use this data on MMIs for all the severely affected and marginally affected districts of Gujarat. Since MMIs are reported from several locations along with their geo-coded locations within the same district, we find the average MMI for each district affected by the earthquake and surveyed in IHDS-1. We re-tabulate MMIs for all the severely and marginally affected districts as presented in appendix tables A2a-A2c. Since MMIs are reported from several locations[21] within the same district, we take an average to get a representative MMI for each district. The online supplementary appendix table S14 shows the average intensity for every district. Since the IHDS-1 data does not provide the geo-coded locations of the surveyed households, we had to use the average intensities at the district level.

Using this variable of intensity, we estimate the following equation:

$$H_{ihjt} = \beta(Younger\ Cohort_i * Intensity_j) + \delta_t + \alpha_{jt} + \mu X_h + \varepsilon_{ihjt} \quad (2)$$

Where, all other variable specifications remaining same as in equation (1) $Intensity_j$ measures the MMI of the earthquake in district *j*. This specification helps us to check if districts with higher intensities have worse health outcomes than the districts with lower intensities.

In order to check the validity of our identification strategy, we further generalize equation (2) to estimate age-specific impact. We construct seven age dummies, that are, dummy for each age 4, 5, and 18 to 22, with individuals aged 23 years in 2005 being the reference category:

$$H_{ihjt} = \sum_{l=4}^{l=5}(age_{il} * Intensity_j)\gamma_{1l} + \sum_{l=18}^{l=22}(age_{il} * Intensity_j)\gamma_{1l} + \delta_t + \alpha_{jt} + \mu X_h + \varepsilon_{ihjt} \quad (3)$$

Where, age_{il} is a dummy variable indicating whether individual *i* is of age *l* in the survey year 2005. Each coefficient γ_{1l} can be interpreted as an estimate of the impact of the earthquake on a given *l* year cohort. Since individuals aged 18 and older in 2005 would have been at least 14 years old at the time of earthquake in 2001, we do not expect their health outcomes measured by height and ZHFA to be affected through the channel of early-life malnutrition caused by earthquake.

[21] However, for five districts, it was reported from only one location.

We plot the coefficients γ_{1l} in Figure 2 and 3 for the outcome variables height and ZHFA respectively. Each dot on the middle line is the coefficient of the interaction between age dummy and the intensity measure. The dashed lines above and below the solid line connects the 95-percent confidence interval for each coefficient. Since our cohort-based analysis as mentioned in specification (2) can only capture average effect on the treated (younger) cohort, the above graph helps us to identify age-specific linear impact, along with presenting evidence for parallel trends (Duflo, 2004).

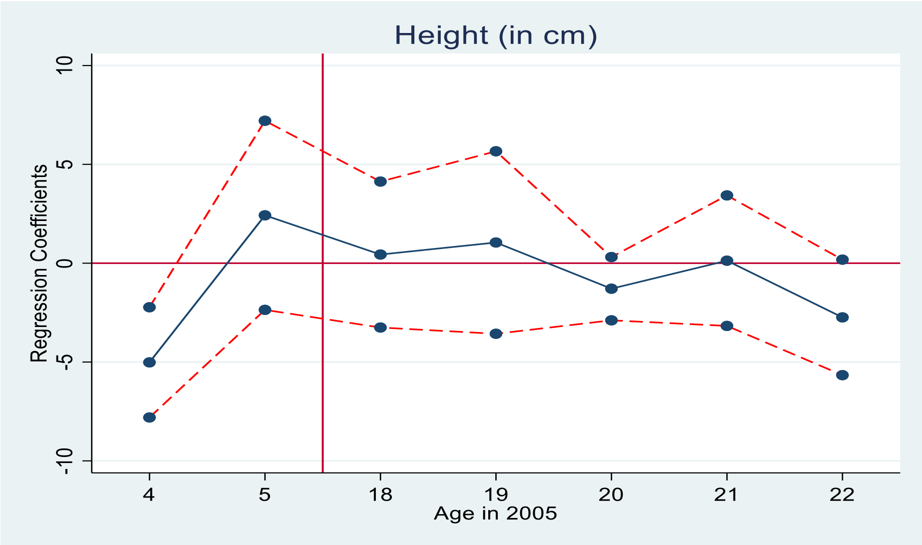

Figure 2: Coefficients of Height on the interactions between age in 2005 and earthquake intensity in the affected districts of Gujarat

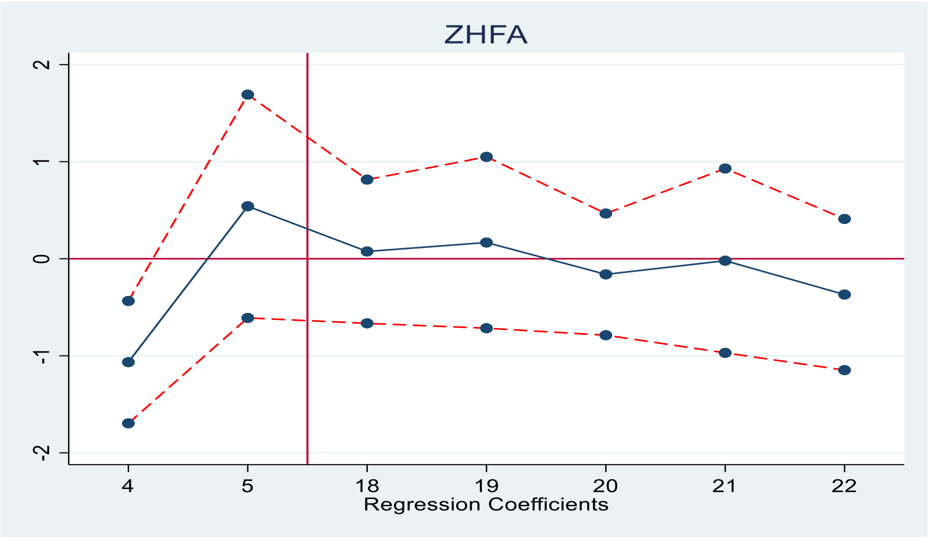

Figure 3: Coefficients of Z-score on the interactions between age in 2005 and earthquake intensity in the affected districts of Gujarat

In Figure 2, none of the coefficients for the age cohorts 18 to 22 is significantly different from zero, which supports our a-priori assumption of parallel trends. As the impact of the earthquake, we expect significantly negative coefficients for both 4 and 5 years old cohorts. However, the negative impact on height seems to be primarily driven by the effect on a 4-year old cohort, as the coefficient for age 5 is small in magnitude and not statistically significant. Individuals whom we expect to be in-utero or were less than a year old at the time of earthquake i.e. aged 4 years old in 2005, have significantly negative coefficients, as expected. Similarly, for the outcome variable ZHFA in Figure 3, none of the coefficients of the interaction terms, except for that of age 4, is significantly different from zero, which indicates about the negative impact on affected children who may have been in-utero or less than a year old during the disaster.

5. Discussion of Results

The impact of the earthquake intensity (in MMI scale), on height and ZHFA outcomes as estimated by equation (2) are presented in Panel A and B of Table 3 respectively. For the earthquake-intensity related estimates in table 3, our sample includes six severely affected and 10 marginally affected surveyed districts. We do not use survey year fixed effects in this specification, because all the affected Gujarat districts in our sample were surveyed in the year 2005. The first columns of both panels present estimates of our full model specifications with birth year fixed effects, district-time linear trend, and household level covariates as mentioned in specification (2). The next two columns are presented for robustness checks. The second columns present estimates without household level covariates. The last columns present estimates of full model along with nine additional household level covariates, which are suspected to be endogenous. In lieu of availability of a baseline survey, we present the last column estimates with few additional presumably endogenous household level variables only for the purpose of robustness checks. The additional covariates are education of the household head, dependent ratio, wealth index measured by the number of assets, primary source of income, sources of drinking water, and toilet facility, with potentials of affecting the health outcomes of the children. Although, mother's health and educational characteristics are strong determinants of stunting, we could not control mother's height because this information is not available for the 18-23 years old women in the counterfactual group. However, inclusion of a few available determinants of stunting such as household head's education (which is expected to be correlated with mother's education), sources of drinking water and toilet facility are expected to improve our precision.

Table 3: OLS estimates of earthquake: Sample of 16 districts of Gujarat

Panel A: Outcome is Height (in cm)			
	(1)	(2)	(3)
VARIABLES	Height	Height	Height
Younger Cohort*Intensity	-2.539*	-2.725**	-1.667
	[1.37]	[1.24]	[1.16]
Observations	297	297	297
Number of Additional Controls	Three	Zero	Nine
Panel B: Outcome is ZHFA in [-6, 6] range			
VARIABLES	ZHFA	ZHFA	ZHFA
Younger Cohort*Intensity	-0.470**	-0.456**	-0.317
	[0.23]	[0.18]	[0.21]
Observations	278	278	278
Number of Additional Controls	Three	Zero	Nine

Data Source: IHDS 1.
Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors clustered at the district-age levels are in parentheses.
Younger cohorts are females who were in-utero or under the age of 3, and older cohorts are females aged 14–19 years, at the time of earthquake in 2001.
Intensity is earthquake intensities of 16 districts of Gujarat which include 6 severely affected and 10 marginally affected districts.
All specifications include age fixed effects, district-specific time trends.
First column includes three covariates, such as, ethnicity (SC, ST, OBC or others), religion (Hindu or others) and residence status (urban or rural); second column is without additional covariates;; third column include all the nine covariates, such as education of the household head, dependent ratio, wealth index, source of income (agriculture or allied activities, agriculture wage labor, non-agriculture wage labor, independent/petty shop, business/salary/pension or others), ethnicity (SC, ST, OBC or others), religion (Hindu or others), source of drinking water (piped, tube well, hand pump or others), toilet facility (open fields or others), and residence status (urban or rural) .
Wealth index is measured by the number of assets owned by the household. Agriculture or allied activities is the reference category for the income source. Others are the reference category for ethnicity and religion both. Piped water is the reference category for the source of drinking water.

As found from the column 1 of table 3, an additional unit of increase (in MMI) of the earthquake significantly reduces the height of the children in younger cohort on average by about 2.54 cm (in panel A), and reduces ZHFA by 0.47 standard deviations (in panel B). One unit increase in MMI causing a magnitude of about 2.54 cm reduction in adult height may look quite a significant negative impact, however, the point to note here is that the MMI scale of devastation in our survey districts range from 6.5 to 9.5. The way the MMI scales are designed on the basis of its level of expected devastations[22], it may range from 1 to 12 in reality, where the major impacts start from 6

[22] Source: US Geological Survey, https://pubs.usgs.gov/gip/earthq4/severitygip.html , accessed on December 2019.

points onwards. Our sample does not have districts with the lower levels of MMI, and the absence of which is expected to pull up average impact due to extreme levels of devastations. Appendix table A2 (a-c) indicates that we have a large number of districts with MMIs on the higher side. Due to a very small sample size, particularly that of the ZHFA sample, we are unable to check non-linearity of this relationship.[23]

Table 4: OLS-DID estimates: Sample of 17 districts of Gujarat and surveyed districts of other states.

Panel A: Outcome is Height (in cm)						
VARIABLES	(1) Height	(2) Height	(3) Height	(4) Height	(5) Height	(6) Height
Younger Cohort*Severely Affected Region	-3.318	-2.937	-3.329	-3.063	-2.711	-3.296
	[2.03]	[1.98]	[2.04]	[2.06]	[2.03]	[2.06]
Observations	2,146	2,146	2,146	1,985	1,985	1,985
Number of Additional Controls	Three	Zero	Nine	Three	Zero	Nine
Number of Districts	98	98	98	88	88	88
Panel B: Outcome is ZHFA (in [-6, 6] range)						
VARIABLES	ZHFA	ZHFA	ZHFA	ZHFA	ZHFA	ZHFA
Younger Cohort*Severely Affected Region	0.058	0.099	0.05	0.086	0.127	0.042
	[0.32]	[0.32]	[0.34]	[0.32]	[0.32]	[0.33]
Observations	2,057	2,057	2,057	1,903	1,903	1,903
Number of Additional Controls	Three	Zero	Nine	Three	Zero	Nine
Number of Districts	98	98	98	88	88	88

Data Source IHDS 1.
Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors clustered at the district-age levels are in parentheses.
In the first three columns, counterfactuals are all districts of Maharashtra, Rajasthan, Madhya Pradesh and eleven districts of Gujarat. In the next three columns, counterfactuals exclude the 10 marginally affected districts of Gujarat. Younger cohorts are females who were in-utero or under the age of 3, and older cohorts are females aged 14–19 years, at the time of earthquake in 2001.
All specifications include age fixed effects, district-specific time trends and survey year fixed effects.
First and fourth columns include three covariates, such as, ethnicity (SC, ST, OBC or others), religion (Hindu or others) and residence status (urban or rural); second and fifth columns are without additional covariates;; third and sixth columns include all the nine covariates, such as education of the household head, dependent ratio, wealth index, source of income (agriculture or allied activities, agriculture wage labor, non-agriculture wage labor, independent/petty shop, business/salary/pension or others), ethnicity (SC, ST, OBC or others), religion (Hindu or others), source of drinking water (piped, tube well, hand pump or others), toilet facility (open fields or others), and residence status (urban or rural) .

[23] The potential selection bias arising due to unavailability of data from all the unaffected districts and the related tests are explained in appendix section III. We use information from the NFHS data to check the potential differences with the missing districts.

Wealth index is measured by the number of assets owned by the household. Agriculture or allied activities is the reference category for the income source. Others are the reference category for ethnicity and religion both. Piped water is the reference category for the source of drinking water.

The double difference estimates of equation (1) for the height and ZHFA outcomes are presented in Panel A and B of Table 4 respectively. The first three columns of table 4 have 98 districts in total, where six are severely affected, treated districts; and remaining 92 are control districts. The control districts include 10 marginally affected and one unaffected districts of Gujarat, 27 districts of Maharashtra, 23 districts of Rajasthan and 31 districts from Madhya Pradesh. Since only one district of Gujarat was surveyed from the list of completely unaffected districts, we check the robustness of our estimates by excluding the 10 marginally affected districts of Gujarat in last three columns.

The first and fourth columns present estimates of the specification of full model (1), including age fixed effects, district-specific time trends, survey year fixed effects, and three household level covariates[24]. Since IHDS-1 was done from November, 2004 to October, 2005, we include survey year fixed effects in all specifications of table 4. For robustness checks in column 2 and 5, we remove the presumably exogenous household level covariates from model (1). The third and sixth columns present estimates from the full model, along with nine additional covariates as discussed in the previous section.

The estimates for the Height (in Panel A) and ZHFA (in panel B) outcomes from table 4 seem inconclusive. Since the intensity measure requiring less strong assumptions seems more convincing methodology to us, our primary interpretation is limited to the intensity measure of

[24] Across all the specifications of every model, we present only the estimates for the variable of interest i.e. the interaction term in the equation (1) & (2).

earthquake wherever possible. However, it is important to note that the size of impact on height in table 4 looks very close to that of the table 3 estimates.

The validity of the unconfoundedness assumption can be assessed by testing for the pre-treatment difference between the characteristics of the treated and control *districts* before the earthquake. Unfortunately, we could not examine this due to unavailability of district level data before the earthquake. In lieu of that, figure 2 and 3, establishing the pre-treatment difference across individuals, along with the following two strategies should be able to justify our identification strategy.

In order to ensure that our results are not mere estimations of any general trend across time or space, we conduct two falsification tests. First, we falsely construct a similar shock received in 1990 so that the women aged 15 to 17 years in 2004-05 who were under the age of 3 in 1990 would become the treated group. Women aged 18 to 23 years old still serves as our control group. Using this newly treated cohort, we re-estimate specifications (1) and (2) and present the estimates for height and ZHFA outcomes in panel A and B of table 5 respectively.

Table 5: Falsification Test: OLS estimates of earthquake with a falsely treated age cohort.

Panel A: Outcome is Height (in cm)	(1)	(2)	(3)
Younger Cohort*Intensity	-2.036		
	[3.10]		
Younger Cohort*Severely Affected Region		-0.891	-0.908
		[2.29]	[2.45]
Survey Year FE	No	Yes	Yes
Observations	184	1,351	1,250
Number of Additional Controls	Three	Three	Three
Number of Districts	16	98	88
Panel B: Outcome is ZHFA in [-6, 6] range			
Younger Cohort*Intensity	0.508		
	[0.36]		
Younger Cohort*Severely Affected Region		-0.413	-0.453
		[0.32]	[0.33]
Survey Year FE	No	Yes	Yes
Observations	178	1,328	1,232
Number of Additional Controls	181	1,342	1,243
Number of Districts	16	97	87

Data Source: IHDS 1.
Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors clustered at the district-age levels are in parentheses.

Younger cohorts are females aged 11-13, and older cohorts are females aged 14–19 years, at the time of earthquake in 2001.
First column includes earthquake intensities of 16 districts consisting of 6 severely affected and 10 marginally affected districts. Additionally, second column includes ten marginally affected districts of Gujarat and one unaffected district from Gujarat and all the surveyed districts of Maharashtra, Rajasthan and Madhya Pradesh as counterfactual districts. Third column excludes the ten marginally affected districts of Gujarat from the counterfactual group.
All specifications include age fixed effects, district-specific time trends. All columns include three covariates, that are ethnicity (SC, ST, OBC or others), religion (Hindu or others) and residence status (urban or rural).

First column corresponds to the specification of the equation (2), whereas second and third columns estimate the equation (1). The only difference between the last two columns is in sample size. Second column has the largest sample with counterfactuals being ten marginally affected districts and one unaffected district of Gujarat, plus all the surveyed districts of Maharashtra, Rajasthan and Punjab. The third column excludes the ten marginally affected districts of Gujarat. All the specifications include three additional controls and all fixed effects along with time trends as mentioned in specification (1). As expected, none of the coefficients of the interaction terms in either of the panels for height or ZHFA seem to be significantly negative.

Table 6: Falsification Test: OLS estimates of earthquake with a falsely treated state.

Panel A: Outcome is Height (in cm)	(1)	(2)	(3)	(4)	(5)	(6)
Affected Cohort*Affected District	-0.661	-0.544	-0.350	-0.198	-1.148	-1.047
	[1.21]	[1.24]	[1.44]	[1.45]	[0.92]	[0.96]
Observations	2,414	2,250	2,252	2,088	2,936	2,772
Treated State	Bihar	Bihar	Chhattisgarh	Chhattisgarh	UP	UP
Number of Additional Controls	Three	Three	Three	Three	Three	Three
Number of Districts	109	99	107	97	135	125
Panel B: Outcome is ZHFA [-6, 6]						
Affected Cohort*Affected District	-0.131	-0.116	-0.264	-0.241	-0.499***	-0.479***
	[0.17]	[0.18]	[0.18]	[0.18]	[0.16]	[0.17]
Observations	2,318	2,162	2,168	2,012	2,814	2,658
Treated State	Bihar	Bihar	Chhattisgarh	Chhattisgarh	UP	UP
Number of Additional Controls	Three	Three	Three	Three	Three	Three
Number of Districts	109	99	107	97	135	125

Data Source: IHDS 1.

Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors clustered at the district-age levels are in parentheses. The treated state differs across columns as mentioned. The counterfactuals in first, third and fifth columns are ten marginally affected districts of Gujarat, additional one unaffected district from Gujarat, plus all the surveyed districts of Maharashtra, Rajasthan and Madhya Pradesh. Second, fourth and sixths column exclude the ten marginally affected districts of Gujarat from the counterfactual districts.

Younger cohorts are females who were in-utero or under the age of 3, and older cohorts are females aged 14–19 years, at the time of earthquake in 2001.

All specifications include age fixed effects, district-specific time trends and survey year fixed effects.

All columns include three covariates that are ethnicity (SC, ST, OBC or others), religion (Hindu or others) and residence status (urban or rural).

Second, we assume that earthquake occurred either in Bihar, or in Chhattisgarh, or in Uttar Pradesh (in alternative specification) and not in Gujarat in 2001, so that all the districts of the corresponding states become the severely affected region (falsely specified as *treated*) in both panels of table 6. The difference between the two columns in each treated state is the sample size of counterfactuals, which follows the same pattern as of last two columns of table 5. As expected, the coefficients in both panels of table 6 for Height or ZHFA outcomes are not statistically significant, except for a very weak significance for ZHFA outcomes in last two specifications with UP as falsely *treated*.

We do not find any heterogeneous effects across groups decided by a few standard determinants of stunting, such as various disadvantaged caste and religious groups (see online supplementary table S12). Checking the heterogeneity across birth order or gender would be interesting too, which could not be performed due to unavailability of the relevant information in our data.

5.1. Potential Mechanisms

A natural disaster like earthquake brings large scale destruction in terms of loss of home, livelihoods, death and injuries of family members at the micro level; and damage to public infrastructures like health centers, schools, roads at the macro level. United States Geological Survey (USGS) data reports more than 0.8 million estimated deaths due to earthquakes across the world from the year 2000 to 2015. Wide scale destruction, leading to unavailability of basic services like nutritious food, clean drinking water (see table 2 indicating to a few of these differences), clothes and shelter, and deteriorated mental health become a big reason of deprivation of essential nutrients and medical services that are required for the pregnant women and children in early childhood. If healthcare supplies were interrupted, have been inadequate or healthcare infrastructures destroyed due to earthquake, mothers bearing child in-utero may not have been able to receive proper ante natal care, which would have affected fetal health. Apart from that, if food supplies were interrupted for a length of time then there would be an insult to in utero health due to poor nutrition of the mother.

Therefore, using the first two rounds of DLHS data, we investigate the impacts of earthquake on the anti-natal investments. The four outcome variables considered as indicators for ante-natal care are: whether any antenatal health worker ever visited the mother during pregnancy, number of visits by the antenatal health worker, whether iron and folic acid tablets were given during the pregnancy, and if tetanus injection was given during the pregnancy.

$$H_{ihjmt} = \beta(Post_i * Severely\ Affected\ Region_j) + €_m + \delta_t + \alpha_{jt} + \mu X_h + \varepsilon_{ihjmt} \ldots(4)$$

Where H_{ihjmt} is one of the above four health outcomes in alternative specification for the woman *i* who belongs to household *h* in district *j* and gave birth in month *m* of year *t*. $Post_i$ is a dummy variable indicating whether the woman gave birth after the earthquake (=1) which also means that the particular observation belongs to DLHS 2. *Severely Affected Region*$_j$ is a dummy variable indicating the individual belonging to one of the five[25] severely affected districts. Remaining surveyed districts of Gujarat, Maharashtra, Rajasthan and Madhya Pradesh were taken as the unaffected region (*Severely Affected Region* =0). All other variable specifications remaining same as before, the vector X_h includes additional variable, such as, the age and education of the women, her husband's education, age in completed years when the women started living with her husband, gender of the last born child, and whether the woman lives in the rural or urban area. We also control for birth-month $€_m$ fixed effects to account for time-variant changes that might have happened at both regions, which could also affect the health outcomes.

Using the same specification and the same data, we also explore if the households with potential mothers in the severely affected regions had received negative shocks through damage of household infrastructures that could also affect their anti-natal health. The two outcomes considered for this part are type of house (that is, whether the household stayed in 'pucca'[26] house) and having drinking water facility.

[25] In the previous analysis we had six severely affected districts – Ahmedabad, Jamnagar, Kutch, Patan, Rajkot, Surendranagar. Patan could not be included in this analysis as the survey for this district was done in the second phase of DLHS 2 which we do not include in the current analysis.

[26] 'Pucca' is a word in Hindi language, which in the context of building means a house built by concrete walls as against built by mud and straws.

Table 7: OLS estimates of earthquake: Sample of 12 districts of Gujarat plus surveyed districts of other states.

Panel A (Source: DLHS1-2):	Shock to Health Services				Shock to Household Infrastructures	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Visit by ANH	No. of Visits by ANH	IFA Tablets Given	Tetanus Injection Given	Type of House 'Pucca'	Drinking Water – Tap/Handpump
Post*Severely Affected Region	-0.058*	-0.380**	-0.067***	-0.014	-0.038	-0.151***
	[0.032]	[0.159]	[0.025]	[0.020]	[0.036]	[0.050]
Observations	25,293	25,293	25,293	25,293	116,664	116,664
R-squared	0.115	0.074	0.216	0.197	0.397	0.282

Panel B (Source: IHDS 1):	Shock to Health Infrastructure (Health facility in numbers)					
	AWC Center	Health Sub-Center	Primary Health Center	Trained Dai	Untrained Dai	Private Dai
Earthquake Intensity	-0.696	-0.132	-0.054	-0.606**	-0.355***	-0.055
	[0.537]	[0.076]	[0.040]	[0.230]	[0.053]	[0.203]
Observations	61	61	61	61	60	61
R-squared	0.092	0.060	0.040	0.161	0.125	0.004

Notes: *** p<0.01, ** p<0.05, * p<0.1; In Panel A, Robust standard errors clustered at the district-birth year and district-interview year levels are in parentheses for column (1) to (4) and (5) to (6). In Panel B, we cluster them at the district level.

In Panel A, 12 districts based on the two rounds of DLHS data include 5 severely affected and 7 marginally affected districts. In the main analysis based on IHDS 1 data, we had six severely affected districts – Ahmedabad, Jamnagar, Kutch, Patan, Rajkot, Surendranagar. Patan is not included in this analysis as the survey for this district was done in the second phase of DLHS 2 which we do not include in the current analysis. Post takes a value 1 if the observation belongs to first phase of DLHS 2 surveyed in 2002 and it takes a value 0 if it belongs to DLHS 1 which was conducted in two phases in 1998 and 1999. We do not use the second phase of DLHS 2 as there was gap of 3 years between the earthquake (2001) and the second phase of DLHS 2 (2004). Columns (1) to (4) include child's month of birth fixed effects, child's birth year fixed effects and district-specific time trends. Columns (5) and (6) include survey year fixed effects and district-specific time trends. All the columns in Panel A include six additional covariates, such as, age of the woman, education of the woman, education of the spouse, age at cohabitation, and residence status (urban or rural). Moreover, columns (1) to (4) include the gender of the last-born child.

In Panel B, 12 districts based on the IHDS 1 data include 5 severely affected and 7 marginally affected districts. In the main analysis based on IHDS 1 data, we had six severely affected districts – Ahmedabad, Jamnagar, Kutch, Patan, Rajkot, Surendranagar. Rajkot is not included in this analysis as the village level survey for this district is not available. Out of 10 marginally affected districts included in the main analysis, Amreli, Bhavnagar and Surat could not be included in this village analysis as the village level survey for these districts are not available.

Panel A of table 7 indicates that the pregnant women in the affected areas seem to have received lesser medical care after the earthquake. Specifically, those women who gave birth post-earthquake and belonged to severely affected region, had 5.8 percent lower likelihood of receiving any antenatal health worker visit, 0.38 lesser number of antenatal visits, 6.7 percent lower likelihood of receiving iron and folic tablets, and 1.4 percent lower likelihood of getting tetanus injection during the last pregnancy. Their likelihood of living in a ‘pucca’ house or having a drinking water facility at home post-earthquake, was 0.04 percent or 0.15 percent lower respectively, as compared to their unaffected counterparts.

Using the IHDS-I village level data (2004-05) and the similar specification as above, we also explore if the earthquake affected districts have higher likelihood of village level health infrastructures being damaged. In this specification, the outcomes considered are village level numbers (availability) of AWC centre, Health sub-centre, Primary health care centre, trained Dai, untrained Dai, and Private Dai. Panel B of table 7 indicates a lower availability of all the above village level health infrastructures in the severely affected villages in period immediately after the earthquake. Specifically, an extra unit of earthquake intensity significantly reduces the number of trained and untrained Dai by 0.61 and 0.36. The earthquake seems to have a negative impact on other village level health infrastructures as well, but due to high standard errors in some of those coefficients we reserve our conclusions in those.

5.2. Mitigating Effects

In order to examine the mitigating effects of provision of public goods, we extend our analysis to check if users of ICDS were able to mitigate the negative impact of earthquake. ICDS is the largest national program in the world which aims to target long-term nutrition and holistic development of children by providing a range of services in one platform. It operates through the

Anganwadi (or childcare) centers (AWCs) located within the villages or the urban wards. Since its arrival with 33 projects in 1975, there has been a rapid expansion with 7073 operational projects with around 1.349 million operational AWCs in 2016, which covers almost all the regions of the country (MoWCD, 2017). For this wider coverage and efficient implementation of the scheme, fund allocation has been increased from Rs. 444 billion (5.91 billion dollars approximately) in Eleventh five-year plan (2007-2012) to Rs. 1235.8 billion (16.46 billion dollars approximately) in Twelfth five-year plan (2012-2017).

Using the available information on the actual consumption of any ICDS component by the households for the last two births after January 2000, we estimate the following equation for the subsample of our younger cohort aged 3-5 years old (during survey) and born after January 2000:

$$H_{ihkt} = \beta_1(NonUser\ in\ severely\ affected\ region_i) + \beta_2(NonUser\ in\ control\ region_i) + \beta_3(User\ in\ control\ region_i) + \pi Male_i + \delta_t + \boldsymbol{\mu X}_h + \boldsymbol{\alpha D}_k + \varepsilon_{ihkt} \quad \ldots\ldots(5)$$

To evaluate the mitigating effects of ICDS, we generate four interdependent binary variables using all possible combinations of ICDS usage and households belonging to *Severely Affected Regions*. The four dummy variables are households who do not use ICDS belonging to severely affected region (*Non-user in severely affected region*), do not use ICDS belonging to marginally affected or unaffected region (*Non-user in control region*), use ICDS while staying in marginally affected or unaffected region (*User in control region*), use ICDS while staying in severely affected region (*User in severely affected region*). The last group being the reference group, we expect $\beta_1$to be significantly negative, as the impact is expected to be more among non-users in comparison to users in severely affected region. Other variables have the same definitions as previous equations, apart from additional male dummy of children, and a vector of district level observables ($\boldsymbol{D}_k$). Since, this specification does not allow us to control for district fixed effects, we control for time invariant differences across the districts (denoted by vector $\boldsymbol{D}_k$) by including four covariates from the 2001 Census data. The covariates are, 1) percentage of villages in a district k having medical facilities, 2) having paved roads, 3) percentage of rural population in the district, and 4) sex ratio in the district.

Table 8: Mitigating effects of ICDS usage in earthquake affected areas on Height and ZHFA for the younger cohort (0-3 years old).

	(1)	(2)
VARIABLES	Height in cm	ZHFA in [-6,6]
ICDS Non-Users in Severely affected region	-6.826*	-1.061*
	[3.54]	[0.54]
ICDS Non-Users in control region	2.080	0.126
	[2.75]	[0.17]
ICDS Users in control region	2.757	0.298**
	[2.69]	[0.14]
Observations	896	807
Age FE	Yes	Yes
Survey Year FE	Yes	Yes
Number of Additional Controls	Eight	Eight

Data Source: IHDS 1.
*** p<0.01, ** p<0.05, * p<0.1, Regressions are estimated by OLS. Robust standard errors clustered at the district level are shown in parentheses.
Control group in terms of space includes all the districts of Maharashtra, Rajasthan, Madhya Pradesh and eleven districts of Gujarat. ICDS users in severely affected region is the reference category.
Eight additional controls are gender of the child, ethnicity (SC, ST, OBC or others), religion (Hindu or others) and residence status (urban or rural), percentage of villages in a district which have medical facility in their village, percentage of villages in a district which have paved road in their village, percentage of rural population in the district, sex ratio.

Our estimates from table 8 indicate that the height and ZHFA are about 6.8 cm and 1.1 standard deviations lower for the non-users in severely affected region as compared to users. The estimate of the third row indicates that among users, the households in unaffected regions seem to have marginally better health outcomes only when ZHFA is considered, but otherwise those households do not seem to have a large difference, which could be a secondary evidence of mitigating effects of ICDS usage. One could worry about the usage of ICDS services being endogenous to the households. We argue that after conditioning on a large number of household and district level observables including birth-year specific fixed effects, the differential impact is primarily generated by the ICDS usage. Moreover, this mitigating ability of the ICDS is supported by the findings of Dhamija and Sen (2020), who find that a 10-13 year old cohort fully exposed to the ICDS during the first three years of their life had about 2.3 cm higher height as compared to their unexposed counterparts.[27]

6. Concluding Comments

The human development literature establishes a strong linkage between early life health and later life welfare outcomes. Any negative shock at this stage creates a lasting impact, and positive inputs targeted to overcome deficiencies at this stage are found to produce strong positive outcomes.[28] In this study, we try to evaluate the impact of one such negative shock on anthropometric outcomes of children. We find it essential to understand the long run consequences of the Gujarat earthquake of 2001, on the children who were in-utero or under the age of three year at the time of earthquake. The massive destruction caused by the earthquake took away the lives of more than 20,000 individuals, and left 166,000 injured. Exploiting the exogenous variation in the exposure to this unfortunate shock and the birth year of children, we find that girls in the younger cohort, exposed to the shock in early years of their lives, seem to have lower height and ZHFA as compared to their unexposed counterparts. The estimates of impact is about 3 cm lower height for earthquake-exposed girls.

The data limitation restricts our estimation of treatment effects to the female cohort in all our specifications because the anthropometric information is not available for the male cohort of

[27] We also examine the heterogeneous effects by gender and birth order of the child (see online supplementary table S13). However, the mitigating effect does not vary by gender or birth order.
[28] See Dhamija and Sen (2020).

18-23 years age. However, in a separate analysis (supplementary table S8), we compare the health outcomes of the boys belonging to younger cohort between the severely affected districts and the remaining unaffected districts using the following regression framework[29]:

$$H_{ihkt} = \beta(Intensity_k) + \delta_t + \boldsymbol{\mu X}_h + \boldsymbol{\alpha D}_k + \varepsilon_{ihkt} \quad \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Here, we restrict the sample to those children who were in-utero or under the age of three at the time of earthquake, as we do not have any counterfactual older cohort in this specification. Hence, our main variable of interest, $Intensity_k$ measures the MMI of the earthquake in district k as discussed in equation (2). $\boldsymbol{D}_k$ represents the same time-invariant district level vector as explained in equation (5). All other variable specifications being same as in equation (2), a simple linear regression estimation among boys sample, indicates that boys belonging to severely affected region at the time of earthquake have lower height and ZHFA on average by 4.9 cm and 0.64 standard deviations respectively.

Our findings conform to the existing literature (Thamarapani, 2021), which also finds a negative effects of early life disasters including that of earthquake. Further, we could also explore few of the potential mechanisms of the negative shock. The affected regions seem to have more households having less ‘pucca’ house, or drinking water facilities after the earthquake. The anti-natal facilities seem to have been affected too. The households having access to ICDS services seem to have lesser impact on their children, which reaffirms the effectiveness of child development services in early life, as found earlier (Dhamija and Sen, 2020).

One potential threat to the validity of the identifying assumption in this analysis is that the socio-demographic composition of mothers giving birth could be correlated with the timing of

[29] The complete regression results are available with authors on request.

exposure to earthquake. To check this, using both rounds of DLHS data, we regress the main variable of interest ($Post_i * Severely\ Affected\ Region_j$) on the following variables - age in completed years when the woman started living with her husband, whether women can read or write, levels of education completed by the women, whether women's husband can read or write, levels of education completed by the women's husband. In these specifications, we also control for birth-year fixed effects δ_t and birth-month $€_m$ fixed effects to account for time-variant changes that might have happened at both regions. We also include time trend of districts to control for unobserved differences over time. Estimates (in appendix table A7) indicate no statistically significant correlations. The impact could be more precisely estimated if we could decompose the impact for the children who faced the exposure in-utero and at the different ages of their early lives. However information on birth year is not available and using age data for this purpose involves higher chances of error. The possibility of error through misreporting of age should also be kept in mind while interpreting the results.

One could also criticize that the impact of earthquake is estimated on the surviving children only, and we are unable to estimate the impact on children who have not been able to survive till later years of their lives. Since, the surviving children are expected to belong to better-off household, along with improved human development outcomes to begin with, what we end up estimating may be a lower bound of true estimate at the maximum.

Additionally, comparison of certain indicators in the sample before earthquake (DLHS-1) and after earthquake (DLHS-2) in table A6 indicates that earthquake affected areas may have been better-off in certain developmental aspects at the baseline. However, if we expect our estimates of impact to be biased due to this, those will be underestimations at the most. Our secondary estimation strategy involves using the marginally affected districts of Gujarat as the counterfactuals because the IHDS-1 does not collect data from more than one unaffected district. This strategy may raise skepticism about magnitude of the estimated impact if the difference in outcomes between marginally affected districts and unaffected districts have been large. However, our primary methodology being based on intensity measures requiring less strong assumptions and the impacts on height by both methods being very close, we believe that the estimates of intensity measures are able to capture true effects at the least.

Trezzi and Porcelli (2014), find that destruction of physical capital as aftereffects of quake causes loss of economic activity, whereas large scale grants from multilateral agencies for reconstruction work boosts economic activity. However, they show that effects of economic activities are non-persistent and tend to be reabsorbed within two years of the earthquake. The earthquake in Gujarat also raised huge concerns inside the country and among the international community, which was followed by the large scale of grants from different domestic and international agencies. It would be interesting to explore if the intervention of funding agencies and other related activities from all around the world were indeed able to boost up large scale reconstruction activity helping improvement of local conditions, and if that may have more than compensated the destruction of physical infrastructures caused by the earthquake (Porcelli and Trezzi, 2019). Since, it is difficult to clearly identify the net outcome on economic activity post-earthquake, we focus on two primary channels. That are, destruction of household infrastructures in the affected districts, and access to health related infrastructures to the households that could affect the health-seeking behaviors of the households.

Therefore, with these results, we add on to the existing literature that attempts to understand the linkage between various natural shocks such and the health, educational outcomes. As established in the existing literature, a 2.5%-3% loss of height in early childhood can lead to cumulative loss in labor market returns (wage) of 2 to 2.4% on average in adulthood)[30]. From a public policy perspective one can recommend that the vulnerable sections of society such as pregnant women and children under the age of three should be provided with sufficient nutrition and care. Sufficient aid and reliefs should also be made available to the other sections of the society at the time of a natural shock because the effects of any negative shock earlier in life is not only observed in the shorter run but they create a lasting impact.

[30] See Appendix section IV for a detailed discussion on this speculation.

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Appendix

Section I: Reasons for using the IHDS data

The National Family Health Survey (NFHS) data would be the only other data set with the similar information. The first two waves of this cross-section data being collected in 1992-93 and 1998-99, we could use those as counterfactuals before the earthquake. However, the post-earthquake rounds were conducted in 2005-06 (NFHS-3) and 2015-16 (NFHS-4), and, the NFHS-3 does not include the district identifiers making it impossible to identify the severely affected districts. While the geo-codes were available for the NFHS-4 only, we could not use the anthropometric information of the 0-4 years old children as even the oldest cohort in this data were born in 2010, that is, 9 years after the earthquake. We could not use the anthropometric data of 15-49 years old eligible mothers as Gujarat was surveyed from January 2016 to June 2016 and the youngest female cohort (i.e. 15 years old) would have been born by the time of the earthquake in 2001. We would not be able to capture any woman who was in-utero at the time of earthquake, if we used this cohort for our analysis. Since, nutrition in-utero is an important determinant of health outcomes in later life, this would have introduced selection bias in our results. Hence, we have used IHDS data instead of NFHS data.

Section II: Reasons for using UK Growth Chart as reference instead of WHO Growth Chart

While one may argue that the WHO 2006 growth charts are more updated growth charts, but it provides the reference charts to calculate HAZ for children aged 0-19 years old. However, our counterfactual group includes females aged 18-23 years old. Therefore, using WHO 2006 Growth Standards for HAZ restricts our counterfactual group to 18-19 years old. In order to check the robustness, we have calculated HAZ for 3-5 years old (treated cohort) and 18-19 years old (counterfactual cohort) using WHO 2006 Growth Standards. Due to this our full sample reduces from 278 to 132 in Panel B corresponding to table 2 and from 2057 (1903) to 1037 (957) in first (last) three columns in Panel B corresponding to table 3. These results are presented in the tables S9 and S10. Reassuringly, the results of this analysis are in line with the main results (note, the estimated effects although statistically insignificant, is economically meaningful).

Section III: Addressing the concerns of potential selection bias arising due to districts missing from the IHDS 1 sample.

IHDS-1 has not surveyed five of the marginally affected districts (Banaskantha, Porbandar, Sabarkantha, Navsari, Valsad) and three of the unaffected districts (PanchMahal, The Dangs and Dohad) as their objective was to present national level estimates instead of district level estimates. Unavailability of data from these districts can potentially generate an upward bias in our estimates if the health infrastructure or health outcomes are poorer in these districts relative to the surveyed districts in marginally affected and unaffected region. To alleviate this concern, we use the village level and child level data from another nationally representative survey of similar nature, that is the National Family Health Survey Data-2 (NFHS-2) surveyed in 1998-99 and compare the village health infrastructure and height of 0-2 years old children in included districts in the IHDS-1 relative to missing districts in IHDS-1 survey. Unfortunately, NFHS-2 has not covered all the missing districts of IHDS-1. However, it gives us an idea of the direction of bias (if there is any) in our results due to unavailability of data from eight districts in IHDS-1. NFHS-2 surveyed five (Banaskantha, Sabarkantha, Valsad, PanchMahal, The Dangs) out of eight districts missing in IHDS-1. We compare the village health infrastructures and height of children from these five districts to nine districts (Amreli, Bharuch, Bhavnagar, Gandhinagar, Junagadh, Kheda, Mahesana, Surat, Vadodra) which were not missing in IHDS-1 and surveyed in NFHS-2 as well. Summary statistics as presented in table S11 do not show any statistical difference in the village health infrastructure and child's height in the districts from marginally affected and unaffected region which were included and excluded in IHDS-1 except in two indicators (that are, the distance from the sub-center and primary health center). This reassuringly increases our confidence that unavailable data from missing districts is unlikely to bring any upward bias in our main results.

Section IV: Speculating the effect size on loss in returns from the labor market

There are a few important literature connecting differential childhood growth to cognitive outcomes, education outcomes, labor market returns, which can be connected to speculate the impact of such an early life shock on those outcomes. However, both the education outcomes and labor market outcomes are also found to work through the channel of cognitive development, as well as background conditions of the child, the parents, the socio-economic conditions and several such factors. Hence, when it comes to quantifying the impact on labor market outcomes, the effect size varies a lot across countries and across studies, based on what all factors have been controlled for. Since the demographic characteristics of population in the western part of India and more so in the state of Gujarat (which shares the border with Pakistan), is very similar to that of Pakistan, we are able to speculate from the existing literature the extent of losses on income and earnings for adults. Following Bossavie et al. (2021), that predicts about 0.8% gains in returns to every centimeter in height, that is, a loss of height of about 2.5cm to 3cm due to Gujarat earthquake is expected to lead to 2%-2.4% losses in returns from labor market. This is very similar to the findings of Vogl (2014) who finds about 2.3% higher returns on hourly wage in Mexico due to a height gain by the same amount. However, the height premium found by Case and Paxon (2010) in the case of the US and UK data is comparatively much higher, due to potential difference in ethnicity, birthplace, education, differential returns to skills and sorting into high paying occupations. Hence while a generalized conclusion on quantification of such a loss is not the right approach, but it definitely helps to get an idea about the extent of the long term loss of earnings.

Table A1: List of Districts used in the main analysis§

Treated	Controlled			
Gujarat	Gujarat*	Maharashtra	Rajasthan	Madhya Pradesh
Ahmedabad	Amreli	Nandurbar	Bikaner	Sheopur
Jamnagar	Anand	Dhule	Churu	Morena
Kutch	Bharuch	Jalgaon	Jhunjhunun	Gwalior
Patan	Bhavnagar	Akola	Alwar	Datia
Rajkot	Gandhinagar	Washim	Bharatpur	Tikamgarh
Surendranagar	Junagadh	Amravati	Dhaulpur	Chhatarpur
	Kheda	Wardha	Karauli	Panna
	Mehsana	Nagpur	Sawai Madhopur	Damoh
	Surat	Bhandara	Dausa	Satna
	Vadodara	Gondiya	Jaipur	Umaria
	Narmada#	Chandrapur	Sikar	Shahdol
		Yavatmal	Nagaur	Sidhi
		Nanded	Jodhpur	Ratlam
		Hingoli	Jalor	Ujjain
		Parbhani	Pali	Shajapur
		Jalna	Ajmer	Dewas
		Nashik	Bhilwara	Dhar
		Thane	Rajsamand	Indore
		Mumbai	Udaipur	West Nimar
		Pune	Chittaurgarh	Barwani
		Ahmadnagar	Kota	East Nimar
		Bid	Baran	Rajgarh
		Osmanabad	Jhalawar	Bhopal
		Solapur		Betul
		Satara		Harda
		Ratnagiri		Hoshangabad
		Kolhapur		Katni
				Jabalpur
				Dindori
				Mandla
				Seoni

* Five marginally affected districts, Banaskantha, Porbandar, Sabarkantha, Navsari, Valsad, and three unaffected districts, PanchMahal, The Dangs and Dohad from Gujarat were not surveyed in IHDS-1.
# Narmada was the only one district which was reported to be unaffected and surveyed in IHDS-1.
§List of districts used for DLHS data related work is presented in appendix table A5.

Table A2a: Earthquake Intensities across different locations in the districts of Gujarat.

District	Location	MMI	Average
Ahemadabad	Not available	7	7.25
Ahemadabad	Not available	7	7.25
Ahemadabad	Not available	7-8	7.25
Ahemadabad	Not available	7-8	7.25
Ahemadabad	Not available	6	7.25
Ahemadabad	Not available	7-8	7.25
Ahemadabad	Not available	7-8	7.25
Ahemadabad	Patdi	8	7.25
Amreli	Not available	7-8	7.5
Anand	Not available	6-7	6.5
Bharuch	Not available	7-8	7.5
Bhavnagar	Not available	7	7
Gandhinagar	Not available	8	8
Jamnagar	Not available	9	8.07
Jamnagar	Balamba	8-9	8.07
Jamnagar	Beraja	5-6	8.07
Jamnagar	Dhrol	8	8.07
Jamnagar	Dudhai	9-10	8.07
Jamnagar	Dwarka	8	8.07
Jamnagar	Okha	8	8.07
Junagadh	Not available	7-8	9.5
Junagadh	Junagadh	11-12	9.5
Kheda	Not available	6-7	6.75
Kheda	Nandiad	7	6.75

Source: Hough et al., (2002)

Table A2b: Earthquake Intensities across different locations in the districts of Gujarat.

District	Location	MMI	Average
Kutch	Adhoi	9-10	8.96
Kutch	Gundala	9-10	8.96
Kutch	Anjar	10-11	8.96
Kutch	Adipur	9-10	8.96
Kutch	Bhachau	9-10	8.96
Kutch	Bhadreshwar	9-10	8.96
Kutch	Bhuj	11-12	8.96
Kutch	Bhujpur	7-8	8.96
Kutch	Bidada	6-7	8.96
Kutch	Chhasra	8-9	8.96
Kutch	Chitrod	8	8.96
Kutch	Deshalpur	6-7	8.96
Kutch	Dholavira	9	8.96
Kutch	Dhori	9-10	8.96
Kutch	Gandhidham	9-10	8.96
Kutch	Kandla	9	8.96
Kutch	Kera Badadia	7	8.96
Kutch	Khavda	9	8.96
Kutch	Kotdi-Roha	9	8.96
Kutch	Mandvi	9	8.96
Kutch	Mota Asambia	10	8.96
Kutch	Nakhatrana	9	8.96
Kutch	Rapar	10	8.96
Kutch	Ratnal	10	8.96
Kutch	Samakhiali	9	8.96
Kutch	Vadala	7-8	8.96
Kutch	Vondh	10	8.96

Source: Hough et al., (2002)

Table A2c: Earthquake Intensities across different locations in the districts of Gujarat.

District	Location	MMI	Average MMI
Mehsana	Not available	7-8	7
Mehsana	Modhera	6-7	7
Patan	Lodhai(lodhi)	10-11	8
Patan	Patan	7-8	8
Patan	Radhanpur	6	8
Rajkot	Bagathala	8-9	7.83
Rajkot	Maliya	8	7.83
Rajkot	Morbi	8	7.83
Rajkot	Navlakhi	8	7.83
Rajkot	Rajkot	7-8	7.83
Rajkot	Wankaner	7	7.83
Surat	Surat	7-8	7.5
Surendranagar	Dhrandadhra	8	8
Surendranagar	Jhinjhuwada	8	8
Surendranagar	Kharaghodha	8	8
Surendranagar	Halvad	8	8
Surendranagar	Kuda	8	8
Surendranagar	Surendranagar	8	8
Surendranagar	Bajana	8	8
Vadodara	Jawaharnagar	10	8.17
Vadodara	Luna	8-9	8.17
Vadodara	Vadodara	6	8.17

Source: Hough et al., (2002)

Table A3: OLS estimates of earthquake: Sample of 16 districts of Gujarat-Removing migration restriction

Panel A: Outcome is Height (in cm)			
	(1)	(2)	(3)
VARIABLES	Height	Height	Height
Younger Cohort*Intensity	-2.237*	-2.308**	-1.197
	[1.18]	[1.08]	[0.97]
Observations	331	331	331
Number of Additional Controls	Three	Zero	Nine
Panel B: Outcome is ZHFA in [-6, 6] range			
VARIABLES	ZHFA	ZHFA	ZHFA
Younger Cohort*Intensity	-0.437**	-0.403***	-0.270
	[0.19]	[0.15]	[0.18]
Observations	311	311	311
Number of Additional Controls	Three	Zero	Nine

Data Source: IHDS 1.
Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors clustered at the district-age levels are in parentheses.

Younger cohorts are females who were in-utero or under the age of 3, and older cohorts are females aged 14–19 years, at the time of earthquake in 2001.
Intensity is earthquake intensities of 16 districts of Gujarat which include 6 severely affected and 10 marginally affected districts.
All specifications include age fixed effects, district-specific time trends.

First column includes three covariates, such as, ethnicity (SC, ST, OBC or others), religion (Hindu or others) and residence status (urban or rural); second column is without additional covariates;; third column include all the nine covariates, such as education of the household head, dependent ratio, wealth index, source of income (agriculture or allied activities, agriculture wage labor, non-agriculture wage labor, independent/petty shop, business/salary/pension or others), ethnicity (SC, ST, OBC or others), religion (Hindu or others), source of drinking water (piped, tube well, hand pump or others), toilet facility (open fields or others), and residence status (urban or rural) .
Wealth index is measured by the number of assets owned by the household. Agriculture or allied activities is the reference category for the income source. Others are the reference category for ethnicity and religion both. Piped water is the reference category for the source of drinking water.

Table A4: OLS estimates: Sample of 17 districts of Gujarat & districts of others states-No migration restrictions

Panel A: Outcome is Height (in cm)						
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Height	Height	Height	Height	Height	Height
Younger Cohort*Severely Affected Region	-3.204*	-2.775	-3.029	-2.913	-2.508	-2.949
	[1.85]	[1.83]	[1.87]	[1.88]	[1.88]	[1.90]
Observations	2,274	2,274	2,274	2,086	2,086	2,086
No. of Additional Controls	Three	Zero	Nine	Three	Zero	Nine
No. of Districts	98	98	98	88	88	88
Panel B: Outcome is ZHFA [-6, 6] range						
VARIABLES	ZHFA	ZHFA	ZHFA	ZHFA	ZHFA	ZHFA
Younger Cohort*Severely Affected Region	0.060	0.113	0.096	0.094	0.147	0.093
	[0.34]	[0.34]	[0.36]	[0.34]	[0.34]	[0.36]
Observations	2,181	2,181	2,181	2,000	2,000	2,000
No. of Additional Controls	Three	Zero	Nine	Three	Zero	Nine
No. of Districts	98	98	98	88	88	88

Data Source IHDS 1.

Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors clustered at the district-age levels are in parentheses.

In the first three columns, counterfactuals are all districts of Maharashtra, Rajasthan, Madhya Pradesh and eleven districts of Gujarat. In the next three columns, counterfactuals exclude the 10 marginally affected districts of Gujarat.

Younger cohorts are females who were in-utero or under the age of 3, and older cohorts are females aged 14–19 years, at the time of earthquake in 2001.

All specifications include age fixed effects, district-specific time trends and survey year fixed effects.

First and fourth columns include three covariates, such as, ethnicity (SC, ST, OBC or others), religion (Hindu or others) and residence status (urban or rural); second and fifth columns are without additional covariates; third and sixth columns include all the nine covariates, such as education of the household head, dependent ratio, wealth index, source of income (agriculture or allied activities, agriculture wage labor, non-agriculture wage labor, independent/petty shop, business/salary/pension or others), ethnicity (SC, ST, OBC or others), religion (Hindu or others), source of drinking water (piped, tube well, hand pump or others), toilet facility (open fields or others), and residence status (urban or rural) .

Wealth index is measured by the number of assets owned by the household. Agriculture or allied activities is the reference category for the income source. Others are the reference category for ethnicity and religion both. Piped water is the reference category for the source of drinking water.

Table A5: List of Districts used in the analysis based on DLHS data.

Treated	Controlled			
Gujarat	Gujarat	Maharashtra	Rajasthan	Madhya Pradesh
Ahmedabad	Banas Kantha	Aurangabad	Bikaner	Balaghat
Jamnagar	Gandhinagar	Buldana	Barmer	Bhind
Kutch	Junagadh	Jalgaon	Jhunjhunun	Gwalior
Rajkot	Mehsana	Gadchiroli	Bhilwara	Datia
Surendranagar	Sabar Kantha	Sangli	Bharatpur	Chhindwara
	Surat	Amravati	Bundi	Chhatarpur
	The Dangs	Wardha	Dungarpur	Guna
		Nagpur	Jaisalmer	Jhabua
		Sindhudurg	Sirohi	Satna
		Thane	Sikar	Narsimhapur
		Chandrapur	Nagaur	Raisen
		Nanded	Ajmer	Sidhi
		Nashik	Chittaurgarh	Sagar
		Pune	Jhalawar	Ujjain
		Ahmadnagar	Churu	Sehore
		Bid		Dewas
		Osmanabad		Dhar
		Satara		Indore
				Vidisha
				East Nimar
				Bhopal
				Betul
				Seoni

Notes: Remaining districts from the four states are not included in the analysis as they could not be matched across the two rounds of DLHS.

Table A6: Difference in means between severely & marginally or unaffected districts of Gujarat & neighboring states

Mean of Variables	Severely Affected	Unaffected	Overall	Difference	Standard Error
Sample for the household level outcome variables: Before Earthquake (Data Source: DLHS-1 in 1998-99)					
Living in Pucca House	0.603	0.312	0.331	0.291***	[0.008]
Drinking water	0.725	0.575	0.585	0.150***	[0.007]
Age of woman	31.217	30.028	30.107	1.189***	[0.121]
Woman’s Education	4.474	3.255	3.336	1.219***	[0.081]
Husband’s Education	6.846	6.394	6.423	0.453***	[0.083]
Woman's ability to read & write	0.539	0.411	0.420	0.127***	[0.008]
Husband's ability to read & write	0.774	0.710	0.714	0.065***	[0.007]
Woman's age at cohabitation	18.290	16.652	16.760	1.638***	[0.045]
Rural	0.563	0.748	0.735	-0.185***	[0.008]
Observations	3919	55480	59399	59399	
Sample limited to the women who gave birth in the last two years of survey					
Visit by Antenatal Health Worker	0.336	0.316	0.317	0.020	[0.018]
Number of Visits	1.254	0.906	0.926	0.349**	[0.114]
IFA Tablets Given	0.714	0.512	0.524	0.202***	[0.017]
Tetanus Injection Given	0.865	0.730	0.738	0.135***	[0.013]
Last born child (male)	0.568	0.538	0.539	0.030	[0.019]
Last born child (birth-year)	1998.117	1997.903	1997.915	0.215***	[0.022]
Last born child (month of birth)	6.086	6.230	6.222	-0.144	[0.131]
Observations	724	11941	12665	12665	
Sample for the household level outcome variables: After Earthquake (Data Source:DLHS-2 in 2002)					
Living in Pucca House	0.586	0.366	0.379	0.221***	[0.008]
Drinking water	0.859	0.781	0.786	0.078***	[0.006]
Age of woman	30.791	29.295	29.389	1.496***	[0.126]
Woman’s Education	5.113	3.943	4.017	1.169***	[0.087]
Husband’s Education	7.115	6.797	6.817	0.318***	[0.085]
Woman's ability to read & write	0.595	0.474	0.481	0.121***	[0.009]
Husband's ability to read & write	0.799	0.740	0.744	0.059***	[0.007]
Woman's age at cohabitation	18.852	17.078	17.190	1.773***	[0.050]
Rural	0.518	0.680	0.670	-0.162***	[0.009]
Observations	3602	53663	57265	57265	
Sample limited to the women who gave birth in the last two years of survey					
Visit by Antenatal Health Worker	0.210	0.227	0.226	-0.017	[0.015]
Number of Visits	0.528	0.501	0.502	0.027	[0.047]
IFA Tablets Given	0.786	0.639	0.648	0.147***	[0.015]
Tetanus Injection Given	0.890	0.773	0.780	0.117***	[0.012]
Last born child (male)	0.528	0.533	0.533	-0.006	[0.019]
Last born child (birth-year)	2001.485	2001.404	2001.409	0.082***	[0.019]
Last born child (month of birth)	6.165	5.965	5.978	0.200	[0.126]
Observations	775	11853	12628	12628	

Table A7: OLS estimates of earthquake: Sample of 12 districts of Gujarat plus surveyed districts of others states.

VARIABLES	(1) Woman's age at cohabitation	(2) Woman's ability to read and write	(3) Education (woman)	(4) Husband's ability to read and write	(5) Education (husband)
Post-Earthquake*Severely Affected Region	0.035	-0.040*	-0.273	-0.036	-0.352
	[0.111]	[0.024]	[0.253]	[0.031]	[0.323]
Observations	25,293	25,293	25,293	25,293	25,293
R-squared	0.128	0.158	0.163	0.081	0.090

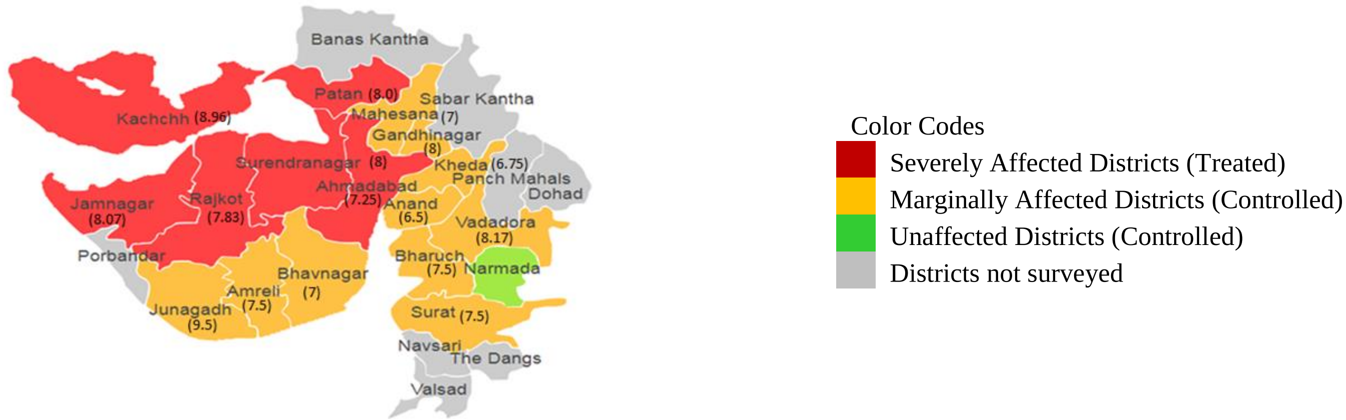
Data Source: DLHS 1 and DLHS 2.

Notes: *** p<0.01, ** p<0.05, * p<0.1 Robust standard errors clustered at the district-birth year levels are in parentheses.

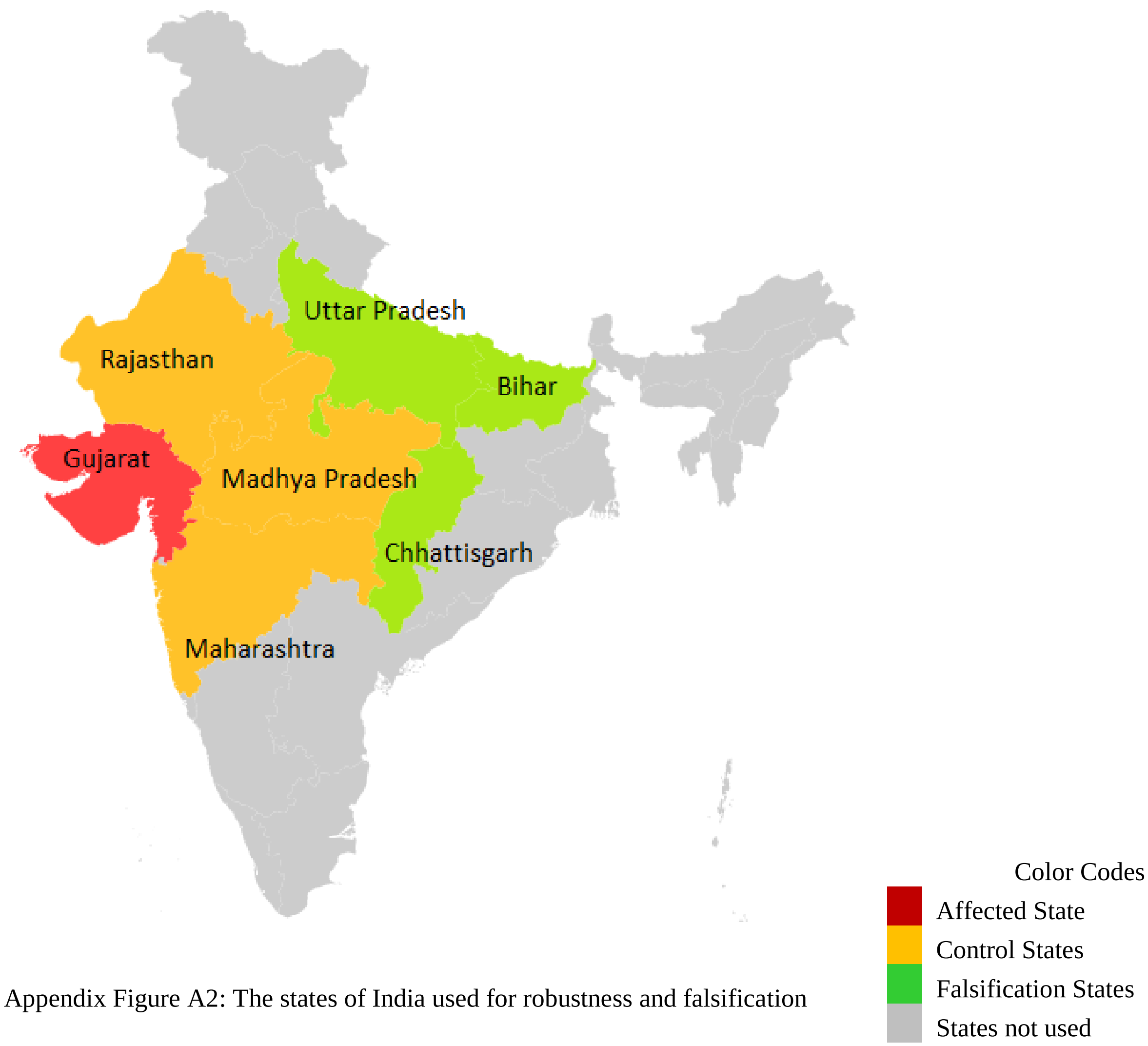
12 districts include 5 severely affected and 7 marginally affected districts. In the main analysis based on IHDS 1 data, we had six severely affected districts – Ahmedabad, Jamnagar, Kutch, Patan, Rajkot, Surendranagar. Patan is not included in this analysis as the survey for this district was done in the second phase of DLHS 2 which we do not include in the current analysis.

Post-Earthquake takes a value 1 if the observation belongs to first phase of DLHS 2 surveyed in 2002 and it takes a value 0 if it belongs to DLHS 1 which was conducted in two phases in 1998 and 1999. We do not use the second phase of DLHS 2 as there was gap of 3 years between the earthquake (2001) and the second phase of DLHS 2 (2004).

All the columns include child’s month of birth, child’s birth year fixed effects and district- specific time trends.



Appendix Figure A1: Sample frame of Gujarat districts – Narmada being the only unaffected district surveyed in IHDS-I, has been combined with unaffected district as a comparison



Appendix Figure A2: The states of India used for robustness and falsification exercise

Supplementary Materials

For tables S3-S7, we check for robustness by clustering standard errors at the district levels. We present those results below corresponding to the tables as named earlier, with a prefix S. E.g, specification of table 3 of main text is presented here as table S3, with only difference being standard errors clustered at district level. S8-14 are new tables.

Table S3: OLS estimates of earthquake: Sample of 16 districts of Gujarat

Panel A: Outcome is Height (in cm)			
	(1)	(2)	(3)
VARIABLES	Height	Height	Height
Younger Cohort*Intensity	-2.539*	-2.725**	-1.667
	[1.29]	[1.13]	[1.04]
Observations	297	297	297
Number of Additional Controls	Three	Zero	Nine
Panel B: Outcome is ZHFA in [-6, 6] range			
VARIABLES	ZHFA	ZHFA	ZHFA
Younger Cohort*Intensity	-0.470**	-0.456**	-0.317*
	[0.21]	[0.16]	[0.16]
Observations	278	278	278
Number of Additional Controls	Three	Zero	Nine

Data Source: IHDS 1.
Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors clustered at the district levels are in parentheses.

Younger cohorts are females who were in-utero or under the age of 3, and older cohorts are females aged 14–19 years, at the time of earthquake in 2001.
Intensity is earthquake intensities of 16 districts of Gujarat which include 6 severely affected and 10 marginally affected districts.
All specifications include age fixed effects, district-specific time trends.

First column includes three covariates, such as, ethnicity (SC, ST, OBC or others), religion (Hindu or others) and residence status (urban or rural); second column is without additional covariates;; third column include all the nine covariates, such as education of the household head, dependent ratio, wealth index, source of income (agriculture or allied activities, agriculture wage labor, non-agriculture wage labor, independent/petty shop, business/salary/pension or others), ethnicity (SC, ST, OBC or others), religion (Hindu or others), source of drinking water (piped, tube well, hand pump or others), toilet facility (open fields or others), and residence status (urban or rural) .
Wealth index is measured by the number of assets owned by the household. Agriculture or allied activities is the reference category for the income source. Others are the reference category for ethnicity and religion both. Piped water is the reference category for the source of drinking water.

Table S4: OLS estimates of earthquake: Sample of 17 districts of Gujarat plus surveyed districts of others states

Panel A: Outcome is Height (in cm)						
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Height	Height	Height	Height	Height	Height
Younger Cohort*Severely Affected Region	-3.318	-2.937	-3.329	-3.063	-2.711	-3.296
	[2.14]	[2.04]	[2.17]	[2.15]	[2.09]	[2.17]
Observations	2,146	2,146	2,146	1,985	1,985	1,985
Number of Additional Controls	Three	Zero	Nine	Three	Zero	Nine
Number of Districts	98	98	98	88	88	88
Panel B: Outcome is ZHFA (in [-6, 6] range)						
VARIABLES	ZHFA	ZHFA	ZHFA	ZHFA	ZHFA	ZHFA
Younger Cohort*Severely Affected Region	0.058	0.099	0.050	0.086	0.127	0.042
	[0.17]	[0.18]	[0.19]	[0.18]	[0.19]	[0.18]
Observations	2,057	2,057	2,057	1,903	1,903	1,903
Number of Additional Controls	Three	Zero	Nine	Three	Zero	Nine
Number of Districts	98	98	98	88	88	88

Data Source IHDS 1.

Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors clustered at the district levels are in parentheses.

In the first three columns, counterfactuals are all districts of Maharashtra, Rajasthan, Madhya Pradesh and eleven districts of Gujarat. In the next three columns, counterfactuals exclude the 10 marginally affected districts of Gujarat.

Younger cohorts are females who were in-utero or under the age of 3, and older cohorts are females aged 14–19 years, at the time of earthquake in 2001.

All specifications include age fixed effects, district-specific time trends and survey year fixed effects.

First and fourth columns include three covariates, such as, ethnicity (SC, ST, OBC or others), religion (Hindu or others) and residence status (urban or rural); second and fifth columns are without additional covariates;; third and sixth columns include all the nine covariates, such as education of the household head, dependent ratio, wealth index, source of income (agriculture or allied activities, agriculture wage labor, non-agriculture wage labor, independent/petty shop, business/salary/pension or others), ethnicity (SC, ST, OBC or others), religion (Hindu or others), source of drinking water (piped, tube well, hand pump or others), toilet facility (open fields or others), and residence status (urban or rural) .

Wealth index is measured by the number of assets owned by the household. Agriculture or allied activities is the reference category for the income source. Others are the reference category for ethnicity and religion both. Piped water is the reference category for the source of drinking water.

Table S5: Falsification Test: OLS estimates of earthquake with a falsely treated age cohort.

Panel A: Outcome is Height (in cm)	(1)	(2)	(3)
Younger Cohort*Intensity	-2.036		
	[3.28]		
Younger Cohort*Severely Affected Region		-0.891	-0.908
		[1.87]	[2.17]
Survey Year FE	No	Yes	Yes
Observations	184	1,351	1,250
Number of Additional Controls	Three	Three	Three
Number of Districts	16	98	88
Panel B: Outcome is ZHFA in [-6, 6] range			
Younger Cohort*Intensity	0.508		
	[0.31]		
Younger Cohort*Severely Affected Region		-0.413*	-0.453*
		[0.21]	[0.24]
Survey Year FE	No	Yes	Yes
Observations	181	1,342	1,243
Number of Additional Controls	Three	Three	Three
Number of Districts	16	97	87

Data Source: IHDS 1.
Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors clustered at the district levels are in parentheses.

Younger cohorts are females aged 11-13, and older cohorts are females aged 14–19 years, at the time of earthquake in 2001.

First column includes earthquake intensities of 16 districts consisting of 6 severely affected and 10 marginally affected districts. Additionally, second column includes ten marginally affected districts of Gujarat and one unaffected district from Gujarat and all the surveyed districts of Maharashtra, Rajasthan and Madhya Pradesh as counterfactual districts. Third column excludes the ten marginally affected districts of Gujarat from the counterfactual group.

All specifications include age fixed effects, district-specific time trends.

All columns include three covariates that are ethnicity (SC, ST, OBC or others), religion (Hindu or others) and residence status (urban or rural).

Table S6: Falsification Test: OLS estimates of earthquake with a falsely treated state.

Panel A: Outcome is Height (in cm)	(1)	(2)	(3)	(4)	(5)	(6)
Affected Cohort*Affected District	-0.661	-0.544	-0.350	-0.198	-1.148	-1.047
	[1.46]	[1.51]	[1.44]	[1.47]	[1.10]	[1.15]
Observations	2,414	2,250	2,252	2,088	2,936	2,772
Treated State	Bihar	Bihar	Chhattisgarh	Chhattisgarh	UP	UP
Number of Additional Controls	Three	Three	Three	Three	Three	Three
Number of Districts	109	99	107	97	135	125
Panel B: Outcome is ZHFA [-6, 6]						
Affected Cohort*Affected District	-0.131	-0.116	-0.264	-0.241	-0.499***	-0.479**
	[0.19]	[0.19]	[0.21]	[0.21]	[0.19]	[0.19]
Observations	2,318	2,162	2,168	2,012	2,814	2,658
Treated State	Bihar	Bihar	Chhattisgarh	Chhattisgarh	UP	UP
Number of Additional Controls	Three	Three	Three	Three	Three	Three
Number of Districts	109	99	107	97	135	125

Data Source: IHDS 1.
Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors clustered at the district levels are in parentheses.

The treated state differs across columns as mentioned. The counterfactuals in first, third and fifth columns are ten marginally affected districts of Gujarat, additional one unaffected district from Gujarat, plus all the surveyed districts of Maharashtra, Rajasthan and Madhya Pradesh. Second, fourth and sixths column exclude the ten marginally affected districts of Gujarat from the counterfactual districts.

Younger cohorts are females who were in-utero or under the age of 3, and older cohorts are females aged 14–19 years, at the time of earthquake in 2001.
All specifications include age fixed effects, district-specific time trends and survey year fixed effects.
All columns include three covariates, that are ethnicity (SC, ST, OBC or others), religion (Hindu or others) and residence status (urban or rural)

Table S7: OLS estimates of earthquake: Sample of 12 districts of Gujarat plus surveyed districts of others states.

Panel A:	Shock to Health Services				Shock to Household Infrastructure	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Visit by ANH	No. of Visits by ANH	IFA Tablets Given	Tetanus Injection Given	Type of House 'Pucca'	Drinking Water – Tap/Handpump
Post*Severely Affected Region	-0.058	-0.380	-0.067*	-0.014	-0.038	-0.151**
	[0.049]	[0.278]	[0.037]	[0.024]	[0.051]	[0.071]
Observations	25,293	25,293	25,293	25,293	116,664	116,664
R-squared	0.115	0.074	0.216	0.197	0.397	0.282

Notes: *** p<0.01, ** p<0.05, * p<0.1; Robust standard errors clustered at the district are in parentheses

12 districts based on the two rounds of DLHS data include 5 severely affected and 7 marginally affected districts. In the main analysis based on IHDS 1 data, we had six severely affected districts – Ahmedabad, Jamnagar, Kutch, Patan, Rajkot, Surendranagar. Patan is not included in this analysis as the survey for this district was done in the second phase of DLHS 2 which we do not include in the current analysis.

Post-Earthquake takes a value 1 if the observation belongs to first phase of DLHS 2 surveyed in 2002 and it takes a value 0 if it belongs to DLHS 1 which was conducted in two phases in 1998 and 1999. We do not use the second phase of DLHS 2 as there was gap of 3 years between the earthquake (2001) and the second phase of DLHS 2 (2004). Columns (1) to (4) include child's month of birth fixed effects, child's birth year fixed effects and district-specific time trends. Columns (5) and (6) include survey year fixed effects and district-specific time trends.

All the columns include six additional covariates, such as, age of the woman, education of the woman, education of the spouse, age at cohabitation, and residence status (urban or rural). Moreover, columns (1) to (4) include the gender of the last-born child.

Table S8: OLS estimates of earthquake on Height and ZHFA for the younger male cohort of (0-3 years old): Sample of 16 districts of Gujarat

VARIABLES	(1) Height in cm	(2) ZHFA in [-6,6]
Intensity	-4.928**	-0.640*
	[2.33]	[0.34]
Observations	139	124
Age FE	Yes	Yes
Number of Additional Controls	Seven	Seven

Data Source: IHDS 1.
*** p<0.01, ** p<0.05, * p<0.1, Regressions are estimated by OLS. Robust standard errors clustered at the district-age level are shown in parentheses.

Intensity is earthquake intensities of 16 districts of Gujarat which include 6 severely affected and 10 marginally affected districts.
Both the specifications include age fixed effects. Moreover, they also include seven covariates, such as, ethnicity (SC, ST, OBC or others), religion (Hindu or others) and residence status (urban or rural), percentage of villages in a district which have medical facility in their village, percentage of villages in a district which have paved road in their village, percentage of rural population in the district, sex ratio.

Table S9: OLS estimates of earthquake on ZHFA based on WHO growth standards: Sample of 16 districts of Gujarat

Outcome is ZHFA in [-6, 6] range			
VARIABLES	ZHFA	ZHFA	ZHFA
Younger Cohort*Intensity	-0.330	-0.334	-0.245
	[0.23]	[0.24]	[0.23]
Observations	132	132	132
Number of Additional Controls	Three	Zero	Nine

Data Source: IHDS 1.

Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors clustered at the district-age levels are in parentheses.

Younger cohorts are females who were in-utero or under the age of 3, and older cohorts are females aged 14–15 years, at the time of earthquake in 2001.

Intensity is earthquake intensities of 16 districts of Gujarat which include 6 severely affected and 10 marginally affected districts.

All specifications include age fixed effects, district-specific time trends.

First column includes three covariates, such as, ethnicity (SC, ST, OBC or others), religion (Hindu or others) and residence status (urban or rural); second column is without additional covariates;; third column include all the nine covariates, such as education of the household head, dependent ratio, wealth index, source of income (agriculture or allied activities, agriculture wage labor, non-agriculture wage labor, independent/petty shop, business/salary/pension or others), ethnicity (SC, ST, OBC or others), religion (Hindu or others), source of drinking water (piped, tube well, hand pump or others), toilet facility (open fields or others), and residence status (urban or rural) .

Wealth index is measured by the number of assets owned by the household. Agriculture or allied activities is the reference category for the income source. Others are the reference category for ethnicity and religion both. Piped water is the reference category for the source of drinking water.

Table S10: OLS-DID estimates on ZHFA based on WHO growth standards: Sample of 17 districts of Gujarat and surveyed districts of others states.

Outcome is ZHFA (in [-6, 6] range)						
VARIABLES	ZHFA	ZHFA	ZHFA	ZHFA	ZHFA	ZHFA
Younger Cohort*Severely Affected Region	0.152	0.27	0.112	0.118	0.247	0.053
	[0.35]	[0.36]	[0.37]	[0.35]	[0.36]	[0.36]
Observations	1,037	1,037	1,037	957	957	957
Number of Additional Controls	Three	Zero	Nine	Three	Zero	Nine
Number of Districts	98	98	98	88	88	88

Data Source IHDS 1.

Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors clustered at the district-age levels are in parentheses.

In the first three columns, counterfactuals are all districts of Maharashtra, Rajasthan, Madhya Pradesh and eleven districts of Gujarat. In the next three columns, counterfactuals exclude the 10 marginally affected districts of Gujarat.

Younger cohorts are females who were in-utero or under the age of 3, and older cohorts are females aged 14–19 years, at the time of earthquake in 2001.

All specifications include age fixed effects, district-specific time trends and survey year fixed effects.

First and fourth columns include three covariates, such as, ethnicity (SC, ST, OBC or others), religion (Hindu or others) and residence status (urban or rural); second and fifth columns are without additional covariates;; third and sixth columns include all the nine covariates, such as education of the household head, dependent ratio, wealth index, source of income (agriculture or allied activities, agriculture wage labor, non-agriculture wage labor, independent/petty shop, business/salary/pension or others), ethnicity (SC, ST, OBC or others), religion (Hindu or others), source of drinking water (piped, tube well, hand pump or others), toilet facility (open fields or others), and residence status (urban or rural) .

Wealth index is measured by the number of assets owned by the household. Agriculture or allied activities is the reference category for the income source. Others are the reference category for ethnicity and religion both. Piped water is the reference category for the source of drinking water.

Table S11: Summary Statistics of village health infrastructure and child's height in the districts included and excluded in IHDS-1. Source: NFHS2

Variables	Districts Excluded in IHDS-1	Districts Included in IHDS-1	Overall	Difference	S.E.
	(1)	(2)	(3)	(4)	(5)
Distance to Health Facilities (in km)					
Sub-Centre	1.200	3.733	2.954	-2.533**	[1.149]
Primary Health Centre	11.850	6.733	8.308	5.117*	[2.639]
Community Health Centre	15.750	12.889	13.769	2.861	[2.779]
Government Dispensary	11.900	8.822	9.769	3.078	[2.311]
Government Hospital	18.750	18.244	18.400	0.506	[3.990]
Private Clinic	6.850	5.422	5.862	1.428	[1.922]
Private Hospital	15.100	12.911	13.585	2.189	[2.319]
Availability of mobile health unit in the village (=1 if yes and 0 otherwise)	0.050	0.044	0.046	0.006	[0.059]
Number of health or family welfare camps in the last year	2.000	3.667	3.154	-1.667	[1.487]
Observations	20	45	65	65	
Height (in cm)	72.265	71.391	71.638	0.874	[0.828]
Observations	224	569	793	793	
Number of Districts	5	9	14	14	

Note: *** p<0.01, ** p<0.05, * p<0.1. Column (1) includes three districts (Banaskantha, Sabarkantha, Valsad) from the marginally affected region and two districts (PanchMahal, The Dangs) from the unaffected region which were not surveyed in the IHDS-1. Column (2) includes nine districts (Amreli, Bharuch, Bhavnagar, Gandhinagar, Junagadh, Kheda, Mahesana, Surat, Vadodra) from the marginally affected region which were surveyed in the IHDS-1.

Table S12: Heterogeneity analysis: OLS estimates of earthquake using a sample of 16 districts of Gujarat

Panel A: Outcome is Height (in cm)		
	(1)	(2)
VARIABLES	Height	Height
Younger Cohort*Intensity*Hindu Religion	-0.259	
	[0.76]	
Younger Cohort*Intensity* Lower Caste		-0.359
		[0.37]
Younger Cohort*Intensity	-2.337*	-2.445*
	[1.27]	[1.26]
Observations	297	297
Number of Additional Controls	Three	Three
Panel B: Outcome is ZHFA in [-6, 6] range		
VARIABLES	ZHFA	ZHFA
Younger Cohort*Intensity*Hindu Religion	-0.171**	
	[0.08]	
Younger Cohort*Intensity*Lower Caste		-0.046
		[0.07]
Younger Cohort*Intensity	-0.346	-0.430**
	[0.22]	[0.20]
Observations	278	278
Number of Additional Controls	Three	Three

Data Source: IHDS 1.
Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors clustered at the district-age levels are in parentheses.
Younger cohorts are females who were in-utero or under the age of 3, and older cohorts are females aged 14–19 years, at the time of earthquake in 2001.
Intensity is earthquake intensities of 16 districts of Gujarat which include 6 severely affected and 10 marginally affected districts.
All specifications include age fixed effects, district-specific time trends.
Both the columns include three covariates, such as, lower caste (=1 if the individual belongs to a household with SC, ST, OBC and 0 otherwise), Hindu Religion (=1 if the individual belongs to a household with Hindu religion and 0 otherwise) and residence status (urban or rural).
We interact the interaction between younger cohort and intensity with the religion dummy and lower caste dummy in alternative specifications.

Table S13: Heterogeneity analysis: Mitigating effects of ICDS usage in earthquake affected areas on Height and ZHFA for the younger cohort (0-3 years old).

	(1)	(2)	(3)	(4)
VARIABLES	Height in cm	Height in cm	ZHFA in [-6,6]	ZHFA in [-6,6]
ICDS Non-Users in Severely affected region*Male	-4.997		-0.499	
	[8.58]		[0.84]	
ICDS Non-Users in control region*Male	-5.744		0.050	
	[4.13]		[0.38]	
ICDS Users in control region*Male	-3.997		0.392	
	[3.98]		[0.37]	
ICDS Non-Users in Severely affected region*Birth Order		2.792		0.184
		[2.95]		[0.12]
ICDS Non-Users in control region*Birth Order		1.449		-0.073
		[2.15]		[0.07]
ICDS Users in control region*Birth Order		1.079		-0.126*
		[2.14]		[0.07]
ICDS Non-Users in Severely affected region	-4.663	-13.364**	-0.747*	-1.517**
	[6.43]	[6.73]	[0.41]	[0.69]
ICDS Non-Users in control region	4.688	-1.299	0.109	0.284
	[4.21]	[2.82]	[0.25]	[0.27]
ICDS Users in control region	4.416	0.374	0.094	0.598***
	[4.16]	[2.63]	[0.22]	[0.22]
Observations	896	896	807	807
Age FE	Yes	Yes	Yes	Yes
Survey Year FE	Yes	Yes	Yes	Yes
Number of Additional Controls	Eight	Nine	Eight	Nine

Data Source: IHDS 1.

*** p<0.01, ** p<0.05, * p<0.1, Regressions are estimated by OLS. Robust standard errors clustered at the district level are shown in parentheses.

Control group in terms of space includes all the districts of Maharashtra, Rajasthan, Madhya Pradesh and eleven districts of Gujarat. ICDS users in severely affected region is the reference category.

Eight additional controls are gender of the child (=1 if male and 0 otherwise), ethnicity (SC, ST, OBC or others), religion (Hindu or others) and residence status (urban or rural), percentage of villages in a district which have medical facility in their village, percentage of villages in a district which have paved road in their village, percentage of rural population in the district, sex ratio. In addition to these eight additional controls, we also include the birth order of the child in columns (2) and (4). We interact the ICDS exposure variables with the gender dummy and birth order in alternative specifications.

Table S14: Average intensity of earthquake in Treated and Control districts (Source: Hough et al. 2002)

District	Average MMI
Treated Districts	
Ahmedabad	7.25
Jamnagar	8.07
Kutch	8.96
Patan	8
Rajkot	7.83
Surendranagar	8
Control Districts	
Amreli	7.5
Anand	6.5
Bharuch	7.5
Bhavnagar	7
Gandhinagar	8
Junagadh	9.5
Kheda	6.75
Mehsana	7
Surat	7.5
Vadodara	8.17