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Early Life Environmental Exposures and Height, Hypertension, and Cardiovascular Risk Factors Among Older Adults in India

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Abstract

Environmental exposures like rainfall and temperature influence infectious disease exposure and nutrition, two key early life conditions linked to later life health. However, few tests of whether early life environmental exposures impact adult health have been performed, particularly in developing countries. This study examines the effects of experiencing rainfall and temperature shocks during gestation and up through the first four years after birth on measured height, hypertension, and other cardiovascular risk factors using data on adults aged 50 and above (N=1,036) from the 2007–2008 World Health Organization Study on Global Ageing and Adult Health (SAGE) and district-level meteorological data from India. Results from multivariate logistic regressions show that negative rainfall shocks during gestation and positive rainfall shocks during the post-birth period increase the risk of having adult hypertension and CVD risk factors. Exposure to negative rainfall shocks and positive temperature shocks in the post-birth period increases the likelihood of falling within the lowest height decile. Prenatal shocks may influence nutrition *in utero*, while postnatal shocks may increase exposure to infectious diseases and malnutrition. The results suggest that gestation and the first two years after birth are critical periods when rainfall and temperature shocks take on increased importance for adult health.

Introduction

A wide range of early life conditions including childhood socioeconomic status; infections and disease environment; and famines, recessions, and pandemics have been linked to later life morbidity and mortality. However, further investigation of long-run impacts of early life environmental exposures on older adult health in the developing world is needed. First, previous studies of older adults have focused largely on developed countries, in part due to the scarcity of high-quality data in developing countries. As developing countries undergo rapid epidemiological transitions, it is important to understand how early life conditions may contribute to their increasing chronic disease burdens. Furthermore, because many of the proposed mechanisms connecting early life exposures and adult health operate only in settings with high infectious disease burdens, it is most appropriate to test them in developing countries with these conditions (Crimmins and Finch 2006). For much of the twentieth century, developing countries lacked widespread access to refrigeration, clean water, and sanitation and experienced heavy infectious disease burdens. Environmental

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conditions are also likely to be particularly important in developing countries where nutrition is highly dependent on local agricultural conditions (which in turn depend heavily on climate) and poor infrastructure exacerbates the impacts of adverse climate conditions. Second, prior studies of older adults in developing countries commonly rely on self-reports of early life conditions and/or adult morbidity. These reports may be subject to recall bias, dependent on individuals' health knowledge or interactions with health care systems, and affected by high levels of underdiagnosis in developing countries (Basu and Millet 2013; Nugent 2008). However, researchers can now draw on representative surveys containing measured health indicators to study older adult health in developing countries. Third, among the set of early life exposures, environmental conditions remain relatively understudied. Season of birth has been found to influence child height (Lokshin and Radyakin 2012) and child mortality (Muhuri 1996), as well as adult cardiovascular disease (CVD) (McEniry and Palloni 2010), in several developing countries. Season of birth patterns are hypothesized to be related to seasonal variations in disease prevalence and food availability, which are primarily influenced by environmental factors like rainfall and temperature (Muhuri 1996; Doblhammer 2004). While studies have examined the effects of environmental conditions on child height (Hoddinott and Kinsey 2001; Skoufias and Vinha 2012) and infant mortality (Bhalotra 2010) in developing countries, only one considered later life outcomes, finding that higher rainfall in the birth year in Indonesia was positively associated with self-rated health and height in adulthood among women, but not men (Maccini and Yang 2009).

This paper focuses on India for several reasons. Slated to become the most populous country by 2028, India has substantial demographic importance (United Nations 2013). However, few studies have examined the effects of early life conditions on older adult health in India even though the population's high rates of infectious diseases coexist with an unusually high burden of diabetes and CVD, which have both been linked to early life antecedents (Murray and Lopez 2002; Osmani and Sen 2003). India experiences high levels of maternal and child malnutrition (underweight, stunting, and wasting), in part related to high levels of exposure to infection (Black et al. 2013; Gragnolati et al. 2005; Stevens et al. 2012). Early life rainfall and temperature conditions are likely to be particularly relevant in India. Relative to other countries, India experiences a substantial amount of inter-annual and spatial rainfall and temperature variation. India's adult population today experienced substantial childhood exposure to infectious diseases strongly influenced by climate conditions (e.g., diarrhea, malaria, cholera). To this day, India's agriculture remains heavily dependent on weather, and this was particularly the case when the adult population was in infancy. Weather-related shocks caused periodic crop failures and famines; for these reasons, accurate measurement and close monitoring of climate conditions has long been a priority in India. India is fairly unique among developing countries in having a long-running series of rainfall and temperature data from a large network of rain gauge stations established in the late 1800s following a major drought and accompanying famine in 1877 (Guhathakurta and Rajeevan 2008; Rajeevan et al. 2006).

Early Life Conditions and Adult Health

Two of the main pathways theorized to connect early life conditions and later life outcomes are physiological changes resulting from (1) unfavorable conditions *in utero* and (2) exposure to infectious and parasitic diseases during infancy and early childhood.

Gestation

Barker's fetal origins hypothesis posits that adverse nutritional conditions experienced *in utero* can "program" organ systems (known as fetal programming or developmental plasticity), predisposing individuals experiencing unfavorable conditions during critical developmental periods to develop CVD in adulthood (Barker 1995; Eriksson et al. 1999). Barker (1997) hypothesized that fetal undernutrition in any trimester would raise later life blood pressure, but only undernutrition in the second and third trimesters would increase the risk of heart disease in adulthood. The proposed mechanisms varied by trimester: down-regulation of growth (first trimester), impaired placental growth and insulin resistance/deficiency (second trimester), and growth hormone resistance/deficiency and impaired growth (to support brain growth at the expense of the trunk in nutrient-poor conditions), related to shortness or thinness at birth (third trimester).

Laboratory studies have consistently documented that nutritional manipulation in pregnancy can produce elevated blood pressure in animal models (Langley-Evans et al. 1996; Langley-Evans et al. 2003; Vehaskari et al. 2001; Woodall et al. 1996). In human populations, the effects of prenatal exposures to famines have been mixed. Studies of the 1918 influenza pandemic generally find deleterious impacts of prenatal exposure on adult CVD and mortality (Mazumder et al. 2010; Myrskylä et al. 2013). Depending on the famine, some studies find that exposure results in higher adult mortality; impaired glucose tolerance; and increased hypertension, obesity, diabetes, and CVD, while other studies find no evidence of increased adult mortality, glucose intolerance, diabetes, or CVD (Huang et al. 2010; Lindeboom et al. 2010; Kannisto et al. 1997; Painter et al. 2005; Stanner et al. 1997; Roseboom, van der Meulen, van Montfrans et al. 2001).

Post-birth

Postnatal exposure to infectious diseases may result in physiological scarring, chronic inflammation, or malnutrition. Scarring refers to permanent physiological impairment resulting from childhood diseases which influences subsequent morbidity and mortality (Preston et al. 1998). Examples of specific diseases that impact adult mortality include tuberculosis, hepatitis B, rheumatic heart disease, streptococcal infections, and diarrhea (Elo and Preston 1992). Streptococcal infections may damage heart valves and impair lung development and function, which increase CVD and respiratory disease in adulthood (Ibid.). In Bangladesh, Brazil, the Gambia, and Guatemala, chronic parasitic and gastrointestinal tract infections such as diarrheal diseases and dysentery result in slower height increases among children (Stephensen 1999). A synergy exists between nutrition and infectious disease exposure: malnutrited children are at greater risk of contracting infectious diseases or more severe infections, while infections reduce food intake and nutrient absorption, increase metabolic requirements, and divert nutrients from routine developmental processes

(Rice et al. 2000; Scrimshaw et al. 1968). Finch and Crimmins (2004) hypothesize that early life infections set off increased chronic inflammation and energy reallocation, which in turn lead to lower height, CVD, and higher mortality in adulthood. Support for this hypothesis comes mainly from studies documenting positive associations between early life and adult mortality among historical European cohorts (Beltrán-Sánchez et al. 2012; Bengtsson and Lindstrom 2000, 2003; Bozzoli et al. 2009). Studies of postnatal early life conditions in developing countries have found that adverse childhood conditions increase the risk of adult CVD, diabetes, and disability (Huang et al. 2011; Kohler and Soldo 2005; Monteverde et al. 2009; Palloni et al. 2005).

Early Life Weather Shocks and Adult Health

Environmental exposures like rainfall and temperature may influence infectious disease exposure and nutrition, two key early life conditions linked to later life health. Positive temperature shocks and positive and negative rainfall shocks can promote the spread of infectious and parasitic diseases. Temperature and rainfall affect the proliferation, range, and survival of disease vectors transmitting malaria, plague, dengue, and yellow fever. Malaria is particularly sensitive to climate conditions: temperature affects parasite and vector development, while rainfall influences mosquito breeding sites and survival (Craig et al. 1999; Craig et al. 2004). Positive rainfall shocks may lead to contamination of water sources, while positive temperature shocks may shorten pathogens’ incubation periods and increase rates of bacterial proliferation. Checkley et al. (2000) found that increases in mean ambient temperature were associated with increases in hospital admissions for diarrhea among Peruvian children. Negative rainfall shocks may increase demand for water and the prevalence of poor hygiene practices such as less frequent bathing and handwashing and contribute to fecal-oral transmission of gastrointestinal diseases (Ibid.). Rainfall and temperature also influence agricultural production. Shocks can have substantial negative impacts on crops and livestock, resulting in increased food prices, lower household income, poorer maternal and infant nutrition, and increased maternal stress. In India, droughts have resulted in sizeable contractions in the agricultural sector and weakened GDP growth (“Monsoon blues” 2009; “India’s climate” 2012).

This study contributes to the existing literature by examining the effects of early life rainfall and temperature shocks on height, hypertension, and other CVD risk factors (obesity, pulse rate, and waist circumference) among older adults in India. I focus on these outcomes because they are measured rather than self-reported and are linked to early life conditions. Hypertension is a risk factor for CVD with documented early life origins, while height reflects to some degree childhood disease and nutrition. Blood pressure is an indicator of cardiovascular functioning and predictive of aging, CVD, and mortality, while height is inversely associated with mortality (Crimmins and Finch 2006; Crimmins et al. 2008).

The proposed hypothesis is that rainfall and temperature shocks adversely affect early life nutrition and disease exposure through their impacts on infectious disease and agriculture. Importantly, these shocks are highly erratic and not easily predicted, indicating that they are unanticipated and plausibly exogenous (“India’s climate” 2012). Shocks can occur either *in utero* or post-birth. Prenatal shocks may lead to fetal undernutrition or maternal stress or infections, resulting in physiological changes like impaired fetal growth, insulin resistance, and growth hormone deficiency. These may increase the risk of adult CVD. Postnatal shocks increase exposure to infectious diseases and malnutrition, causing physiological scarring, chronic inflammation, and impaired growth. These may lead to lower adult height and increased risk of CVD. Thus, height is expected to be primarily related to postnatal exposures while hypertension and other CVD risk factors may be influenced by both pre- and postnatal exposures. This study addresses the following questions: (1) Do early life rainfall and temperature shocks affect height, hypertension, and other CVD indicators among older adults in India? (2) Are there critical periods when these shocks are particularly important? (3) Are these shocks more important during certain seasons?

Data and Methods

Data

Data are from the WHO Study on Global Ageing and Adult Health (SAGE) India survey fielded in Assam, Karnataka, Maharashtra, Rajasthan, Uttar Pradesh, and West Bengal in 2007–2008. SAGE was designed to be comparable to other aging studies like the Health and Retirement Study and nationally representative of the population aged 50+ in India (Kowal et al. 2012). In order to ensure that rainfall and temperature shocks corresponded to those experienced by respondents around the time of birth, I restricted the analysis to respondents who reported month of birth and are never-movers. The final sample consisted of 1,036 individuals aged 50+ who met those criteria and were non-missing on other variables of interest.

The weather data come from the Climate Research Unit (CRU) TS2.1 dataset collected by the Tyndall Centre for Climate Change Research, University of East Anglia (India Water Portal 2012). This dataset contains monthly temperature and rainfall measures from district rainfall stations produced from interpolations based on high-resolution climate grids (Mitchell and Jones 2005). Accurate measurement and close monitoring of climate conditions has long been a priority in India due to the strong dependence of agriculture on weather (Kumar and Parikh 2001). While weather may vary within districts, districts are a much finer unit of analysis than those used in previous studies. These data were linked to SAGE respondents by matching on month, year, state, and district of birth (assumed to be current district for never-movers). Studies of older adults in developed countries have used historical, administrative, or vital statistics data linkages to provide more accurate information on early life conditions. Leveraging other sources of data has been rarer in developing countries. This study uses rainfall and temperature measures to augment the existing information on childhood conditions in surveys of older adults. While not without their own limitations, these measures directly measure factors hypothesized to influence *in utero* and postnatal nutrition and disease exposure and are not subject to the biases associated with retrospective reporting of early life conditions.

Measures

Adult Outcomes—The outcome measures were height, hypertension, and an index of four CVD indicators. Systolic and diastolic blood pressure were based on the average of three measurements. The three binary hypertension measures were: high-risk systolic (≥140 mm Hg or reported antihypertensive medication usage), high-risk diastolic (≥90 mm Hg or reported antihypertensive medication usage), and high-risk combined blood pressure (systolic ≥140 mm Hg or diastolic ≥90 mm Hg or reported antihypertensive medication usage). The binary CVD index indicated whether the individuals had any of the following: high-risk combined blood pressure, high-risk waist circumference (>102 cm, males; >88 cm, females), high-risk pulse rate (≥90 beats per minute), or obesity (≥30 kg/m^2 based on measured weight and height).[1] These cutpoints follow current WHO (2003) and NHLBI guidelines and have been used in prior studies (e.g., Crimmins et al. 2005; Kearney et al. 2005; Seeman et al. 2008). The height outcome was whether respondents fell within the lowest height decile (1.561 meters, males; 1.426 meters, females).[2]

Shocks—Weather shocks were constructed from monthly rainfall (m) and minimum temperature (°C) series. A positive rainfall (temperature) shock was defined as the number of months that rainfall (temperature) exceeded the 90th percentile of rainfall (temperature) for a given month and district in 1913–1962. A negative rainfall shock was defined as the number of months rainfall fell below the 10th percentile for a given month and district in 1913–1962.[3] I also tested whether the season of exposure mattered using the Indian Meteorological Department definitions: winter (January–February), summer (March–May), monsoon (June–September), and post-monsoon (October–December) (Attri and Tyagi 2010). I examined the effects of both prenatal and postnatal rainfall and temperature shocks up through the first 4 years after birth.

Controls—The basic model (Model 1) controls for age and sex. The full model (Model 2) additionally controls for state of residence, urban/rural residence,[4] season of birth, mother’s education, father’s occupation,[5] respondent’s education, religion, and caste (descriptive statistics and variable categories shown in Table 1). As age misreporting may be a concern, especially among the elderly, the use of five-year age groups and an open-ended interval beginning at age 75 mitigates imprecision in age reporting. Models estimated on younger subsamples (individuals born after 1950 and individuals aged 50–74) indicate that the conclusions are robust to restricting the sample to younger individuals.

Methods

Logistic regression was used to model the relationships between rainfall and temperature shocks and each of the adult health outcomes: whether individuals had high-risk systolic, diastolic, or combined blood pressure; whether they had any of four CVD risk indicators;

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[1] Results were similar when a linear outcome measure with values ranging from 0–4 instead of 0-1 was used. This measure is similar to comorbidity indices or risk factor scores that use weighted or un-weighted sums to indicate the risk and/or severity of disease (Charlson et al. 1994; Wilson et al. 1998).

[2] Models using the bottom quartile cutoff for height are similar to those presented in the main text.

[3] Prior studies of weather shocks used cutpoints ranging from the 5th–25th and 75th–95th percentiles (Adhvaryu et al. 2013; Burke et al. 2014; Jayachandran 2006; Kumar et al. 2014). Results using the 20th and 25th percentiles for negative shocks and the 75th and 80th percentiles for positive shocks are similar to those presented in the main text.

[4] SAGE includes data on respondents’ current state of residence and whether they have always lived in their current village/town/city. Respondents who responded yes to the last item were designated never-movers, and their current state, district, and rural/urban status are assumed to be their state, district, and rural/urban status at birth.

[5] Agricultural occupation indicates those classified as Skilled Agricultural and Fishery Workers (International Standard Classification of Occupations-88).

and whether they fell within the lowest height decile. The models examine the effects of shocks experienced during the 9-month gestational period and each of the three trimesters; a 9-month post-birth period and each of the corresponding three 3-month periods (the first 0–3, 3–6, and 6–9 months after birth); and the first 4 years after birth (1-year intervals). Additional models consider whether temperature shocks in the summer or rainfall shocks in monsoon season were particularly important. All estimates include survey weights to adjust for complex survey design. Predicted probabilities are estimated comparing the difference in the likelihood of having the outcomes between individuals with 0 versus 1 month of exposure, and between individuals with 0 versus the mean months of exposure. All other variables were set at their mean values.

This paper’s main purpose is to examine whether early life rainfall and temperature shocks impact adult health. Supplementary analyses tested whether these associations differed by gender, mother’s education, father’s occupation, caste, religion, and urban/rural status using interactions between these characteristics and weather shocks (available upon request). Unless otherwise noted, these interactions were not statistically significant, so the analysis focuses on the main effects models.

Results

Gestation

Table 2 presents odds ratios and predicted probabilities from logistic regressions modeling exposure to negative rainfall shocks during gestation. Experiencing negative rainfall shocks during the 9-month gestational period increased the odds of high-risk systolic (OR=1.26, 95% CI=1.04–1.52), diastolic (OR=1.32, 95% CI=1.10–1.57), and combined blood pressure (OR=1.40, 95% CI=1.17–1.67) and the odds of having a CVD risk factor (OR=1.38, 95% CI=1.16–1.63). When exposure was broken down by trimester, the effects were concentrated in the second and third trimesters. The differences in the predicted probability of having hypertension or a CVD risk factor between individuals with no exposure and those with one month of exposure to negative rainfall shocks during gestation ranged from 0.04–0.08 points or 18–27 percent. These differences are similar in magnitude to differences in predicted probabilities of being disabled between those who did and did not experience poor early life conditions (0.06–0.07 points or 30–39 percent) reported by Monteverde et al. (2009) for elderly populations in Latin America and the Caribbean. Supplementary analyses indicated that the hypertension effects were concentrated among those whose mothers had no schooling and whose fathers had agricultural occupations. Negative rainfall shocks were not significantly related to height, and positive rainfall and temperature shocks were not significantly related to any outcomes.

Post-birth: 9 Months

Table 3 presents odds ratios and predicted probabilities from logistic regressions modeling exposure to postnatal rainfall shocks. Positive rainfall shocks during the 9-month post-birth period were associated with increased odds of high-risk systolic (OR=1.21, 95% CI=0.96–1.54), diastolic (OR=1.21, 95% CI=0.94–1.55), and combined blood pressure (OR=1.29, 95% CI=1.01–1.64) and of having a CVD risk factor (OR=1.21, 95% CI=0.97–1.52). The effects were largely concentrated in months 3–6 after birth and during monsoon season. Differences in predicted probabilities of having hypertension or a CVD risk factor between those with no exposure and those with one month of exposure to positive postnatal rainfall shocks ranged from 0.04–0.06 points. Positive rainfall shocks were not significantly associated with height.

Negative rainfall shocks during the post-birth period were associated with lower height. Experiencing an additional month of rain below the 10^{th} percentile during the post-birth period increased the odds of falling within the lowest height decile (OR=1.39, 95% CI=1.11–1.75). This effect was concentrated mainly during months 6–9 after birth (OR=1.68, 95% CI=1.20–2.35) and monsoon season (OR=2.56, 95% CI=1.17–5.62). Compared to individuals with no exposure to negative rainfall shocks during the 9-month post-birth period, those with a month of exposure experienced 0.02 point higher predicted probabilities of falling within the lowest height decile. Supplementary analyses suggest that those whose mothers had no schooling were more likely to experience negative height effects from postnatal negative rainfall shocks. Postnatal negative rainfall shocks were not associated with hypertension or CVD risk factors.

Table 4 presents odds ratios and predicted probabilities from logistic regressions modeling exposure to postnatal temperature shocks. Positive temperature shocks were associated with higher odds of low height (OR=1.39, 95% CI=1.11–1.73). Positive temperature shocks during months 6–9 after birth (OR=1.48, 95% CI=0.94–2.31) and specifically in summer (OR=2.01, 95% CI=0.89–4.53) were associated with higher odds of falling within the lowest height decile. Compared to individuals with no exposure to temperature shocks, those with a month of exposure had 0.02 point (20–36 percent) higher predicted probabilities of falling within the lowest height decile. Supplementary analyses suggest that those whose fathers had agricultural occupations were less likely to experience negative height effects from postnatal positive temperature shocks. Postnatal positive temperature shocks were not associated with hypertension or CVD risk factors.

Post-birth: 4 Years

Tables 5 and 6 present results from logistic regressions modeling associations between rainfall and temperature shocks during the first four years after birth and the outcomes of interest. Most effects were concentrated during the first and second years. Positive rainfall shocks in the first year increased the odds of having high-risk systolic (OR=1.21, 95% CI=1.01–1.46), diastolic (OR=1.22, 95% CI=1.00–1.49), and combined blood pressure (OR=1.31, 95% CI=1.08–1.60) and of having a CVD risk factor (OR=1.21, 95% CI=1.01–1.46). Negative rainfall shocks in the first two years were associated with significantly increased odds of falling within the lowest height decile. The odds ratios were 1.44 (95% CI=1.16–1.78) for the first year and 1.41 (95% CI=1.08–1.84) for the second year.

Positive temperature shocks in the first year (OR=1.43, 95% CI=1.15–1.78) were associated with significantly increased odds of falling within the lowest height decile. Positive temperature shocks during summer months in the first (OR=1.59, 95% CI=0.99–2.56) and second (OR=1.75, 95% CI=1.13–2.71) years were also unfavorable for adult height.

Discussion

This study extends previous research by examining whether pre- and post-natal rainfall and temperature shocks are related to measured height, blood pressure, and an index of CVD risk factors in a sample of older Indian adults. Negative rainfall shocks during gestation and positive rainfall shocks in the post-birth period significantly increased the odds of adult hypertension and having a CVD risk factor. Postnatal negative rainfall shocks and positive temperature shocks up through the first two years of life significantly increased the odds of lower height. Consistent with the prior literature, these results identify gestation and the first two years after birth as critical periods for early life exposures.

Negative rainfall shocks during gestation (particularly the third trimester) may result in adverse *in utero* conditions, inducing permanent physiological changes which increase the risk of adult hypertension and CVD. These adverse conditions may result from the impacts of insufficient rainfall on maternal nutrition and household economic well-being. Droughts have substantial impacts in India: the 1979 drought resulted in a 13 percent contraction in the agriculture sector and a 5 percent shrinking of the economy, while the 2002 drought caused by failed monsoon rains resulted in a 7.2 percent contraction in the agricultural sector and a 2 percent decline in GDP growth (“Monsoon blues” 2009). While comparable figures are not available for the period when these cohorts were in infancy and early childhood, the deleterious impacts of droughts were likely equally if not more important given the lack of irrigation and insurance mechanisms. The link between negative rainfall shocks and hypertension and other CVD risk factors may result from the contemporaneous effects of crop failures on poorer maternal nutrition. Several candidate mechanisms have been proposed for the intrauterine programming of hypertension: maternal undernutrition may lead to permanent structural changes in the kidneys, elevating risks for adult cardiorenal disease, and to altered cardiac development and function, rendering the heart more vulnerable to damage in later life (McMillen and Robinson 2005). The importance of the third trimester is consistent with studies finding that adults with third trimester exposure to the Dutch famine had increased blood pressure and impaired glucose tolerance (Ravelli et al. 1998; Roseboom, van der Meulen, van Montfrans et al. 2001).

Positive rainfall shocks after birth are associated with increased hypertension and other CVD risk factors in adulthood. Heavy rainfall may increase exposure to diarrheal and other gastrointestinal diseases, cause floods and crop failures, and promote vector proliferation (Ahern et al. 2005; Doblhammer 2004). Infectious disease exposure and malnutrition in early childhood have been linked to elevated adult CVD risk through scarring and chronic inflammation (Buck and Simpson 1982; Elo and Preston 1992; Finch and Crimmins 2004).

Negative rainfall shocks and positive temperature shocks in the post-birth period increased the odds of low height. Height reflects in part both nutrition and infectious disease exposure in childhood. As discussed above, droughts and particularly failed monsoons have major impacts on agricultural production and income in India. Negative rainfall shocks may result in poorer infant and child nutrition, and malnutrition increases the risk of contracting or having more severe cases of diarrheal disease, acute lower respiratory infections, and pneumonia (Rice et al. 2000). Limited water availability may also result in poorer hygiene practices and increased exposure to infectious diseases. Children with diarrheal disease often become severely dehydrated, and insufficient rainfall may exacerbate the impacts of diarrheal diseases. The negative rainfall shock results suggest that environmental conditions during monsoon season may be particularly salient. Important crops such as rice, sugar cane, and oilseeds are typically sown during this season ("India's failing monsoon" 2009).

Positive temperature shocks may impact child nutrition in part through crop failures, but the most likely pathway is increased exposure to infectious and parasitic diseases. Higher temperatures may increase infections among infants and children by expanding the range of vector-borne diseases; increasing demand for water and the prevalence of poorer hygiene practices; and promoting food spoilage. The incidence of waterborne infectious diseases affecting the gastrointestinal tract is correlated with warmer temperatures and flooding (Doblhammer 2004). A positive relationship exists between higher ambient temperatures and contamination of weaning foods, which in turn is strongly associated with diarrheal disease and malnutrition among children (Checkley et al. 2000; Motarjemi et al. 1993). Black et al. (1982) found that in Bangladesh, food samples stored at higher temperatures had higher *E. coli* levels, and the proportion of food fed to children of weaning age containing *E. coli* was strongly associated with diarrheal disease incidence.

Breastfeeding is likely to play an important role in the impacts of early life rainfall and temperature shocks. Children's exposure to disease pathogens in their environment depends on the length of breastfeeding and timing of introduction of weaning foods, which influence how long infants receive protection from maternal antibodies and when they are exposed to food- and water-borne diseases. Rates of infection are particularly high during and after weaning. The results from this study suggest that weather shocks experienced in months 3–9 and years 0–2 post-birth were most strongly associated with negative adult outcomes. Very few fertility surveys collected estimates of breastfeeding duration in India, even in recent decades (Jain and Adlakha 1982; Visaria, Visaria, and Jain 1995). The best estimates of exclusive breastfeeding from studies conducted closest to when the adults in this sample were born date from the 1950s-1980s and range from 6–12 months (Prema and Ravindranath 1982; Scrimshaw et al. 1968; Visaria 1988). It is highly unlikely breastfeeding in earlier decades was shorter than in later periods – sustained fertility declines did not start until the early 1970s in India, and the predominant trend for developing countries for most of the past century has been for breastfeeding duration to decline, not increase. The general consensus is that nonexclusive breastfeeding in India was universal and of long duration, typically lasting up until the next pregnancy. Studies place the average duration of nonexclusive breastfeeding at approximately two years (Jain and Adlakha 1982; Nath et al. 1994; Visaria 2004; Visaria et al. 1995). The persistence of the effects of positive temperature shocks through the first two years after birth is thus within the range of when nonexclusive breastfeeding is ending and children who are being weaned experienced increased exposure to infections.

Limitations

This study has important limitations that should be addressed in future investigations. Using survey data on older adults presents key challenges. This study focuses on older adults for three main reasons: the early life conditions hypothesized to impact adult health correspond closely to the early life conditions of current cohorts of older adults, the prevalence of chronic diseases is higher among older adults, and SAGE is representative of the population aged 50+. However, older adults' retrospective reporting of parental characteristics or events occurring much earlier in life may lack precision and be subject to recall bias. The sample consists of adults aged 50+, and it is unclear how results may be influenced by selective survival to age 50.

Given the paucity of reliable data about early life conditions of older adults in developing countries, it is difficult to identify specific mechanisms connecting early life conditions and older adult health. For example, potentially important variables like birth order, sibship size and sex composition, household size in childhood, and infant mortality in the birth year are not available but may mediate the effects of rainfall and temperature shocks. Whether early life conditions have long-run impacts may be highly sensitive to local-, household-, and community-level conditions; however, data at very local levels of resolution are scarce in developing countries today, let alone for the early twentieth century.

Another challenge is that on net, countervailing effects of weather shocks may cancel each other out (e.g., if both acquired immunity and scarring are operating), and identifying these separate pathways may not be possible (particularly due to the synergy between malnutrition and infectious disease). The literature and theories on early life conditions and adult health would benefit from further efforts to identify the specific conditions under which different early life conditions do or do not impact adult health.

This study relies on the accuracy of respondents' reporting of month and year of birth, and age misreporting may be an issue, particularly among older adults. However, heaping was much less of a problem for month and year of birth than for age in this sample. Respondents who reported month of birth were more likely to be male, better educated, reside in urban areas, and somewhat younger than the entire sample of adults aged 50+. However, it is unlikely that nonresponse to the month of birth question varied systematically by month of birth (e.g., there is no evidence suggesting that individuals born in June would be any less likely than individuals born in December to report their month of birth). Measurement error in month of birth is expected to be mean zero; generally, this should result in attenuation bias and conservative estimates (Stefanski and Carroll 1985). To the extent that inclusion in the sample is conditional on reporting month of birth, the results are internally valid but may not be generalizable to the broader population. Observable characteristics indicate that individuals who report their month of birth came from families of higher socioeconomic status; these families may have been better able to compensate effectively for weather shocks and these individuals may have been less susceptible to experiencing long-run adverse effects. Thus, this study may produce conservative estimates of the impacts of early life weather shocks.

Women were less likely to report their month of birth than men, restricting the ability of this study to examine sex differences. Among the sample of respondents who reported month of birth, there were clear gender differences in their characteristics. Women who reported month of birth were of higher socioeconomic status: relative to men who reported month of birth, they were younger, better educated and had mothers who were better educated, more likely to have fathers with non-agricultural occupations, more likely to be Muslim, and more likely to live in rural areas and certain states (Table 1). If these women came from more advantaged families that were better able to compensate for shocks, it is possible that the impacts of rainfall and temperature shocks among this subsample may be more muted than among the general population. Since several studies find sex differences in programming by early environments, this is an important area of investigation for future studies.

Conclusion

This study provides support for the hypothesis that early life rainfall and temperature shocks have long-run impacts on measured health outcomes among older adults in India. Gestation and the first two years after birth are critical periods during which exposure to weather shocks is associated with increased hypertension, increased CVD risk, and lower height in adulthood. Negative rainfall shocks experienced during gestation and positive rainfall shocks experienced after birth significantly increase the odds of hypertension and having a CVD risk factor in adulthood, while negative rainfall shocks and positive temperature shocks experienced after birth significantly increase the odds of low height. These findings provide some insight into the potential mechanisms connecting early life conditions and adult health. For prenatal exposures, nutritional conditions *in utero* and associated physiological changes are likely to be operating, while for postnatal exposures, increased exposure to infectious diseases and malnutrition is likely to be connecting early life conditions and adult outcomes. Months 3–9 and the first two years after birth emerge as critical periods, suggesting that individuals may be particularly vulnerable to adverse environmental conditions during the weaning period.

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Table 1

Descriptive statistics, distribution (%) or mean (SD), males and females aged 50+, SAGE India (2007–2008)

	Males 880 (89%)	Females 156 (11%)	Total 1,036		Males 880 (89%)	Females 156 (11%)	Total 1,036
Socioeconomic Characteristics							
Age Group				*Season of Birth*			
50–54	27.9	42.7	29.6	Winter	19.5	17.1	19.3
55–59	28.1	18.4	27.0	Summer	23.3	31.4	24.2
60–64	13.6	19.1	14.2	Monsoon	40.1	36.4	39.7
65–69	13.4	9.6	12.9	Post monsoon	17.2	15.1	16.9
70–74	11.4	8.4	11.0	*State of Residence*			
75+	5.7	1.9	5.3	Assam	1.8	3.9	2.1
Mother's Education				Karnataka	12.7	26.9	14.3
No formal education	85.2	67.4	83.2	Maharashtra	23.8	29.0	24.4
Less than primary	8.4	19.2	9.6	Rajasthan	11.3	1.8	10.3
Primary	3.8	6.9	4.1	Uttar Pradesh	28.3	0.9	25.2
Secondary +	2.6	6.5	3.1	West Bengal	22.0	37.6	23.8
Father's Occupation				*Urban/Rural Residence*			
Non-agricultural	46.9	66.3	49.1	Rural	69.2	58.4	67.9
Agricultural	53.1	33.7	51.0	Urban	30.9	41.6	32.1
Respondent's Education				*Religion*			
No formal education	7.2	44.4	11.4	Hinduism	89.2	80.0	88.2
Less than primary	9.1	9.2	9.1	Islam	6.3	16.4	7.5
Primary	15.9	16.1	15.9	All other	4.4	3.6	4.3
Secondary	21.5	11.6	20.4	*Scheduled Caste or Tribe*			
High school	27.0	8.7	24.9	No	83.3	82.5	83.2
College +	19.3	10.0	18.2	Yes	16.7	17.5	16.8
Adult Outcomes							
High-Risk Systolic Blood Pressure[a]				*Height (m)*			
Normal	72.6	62.5	71.5	≤ 10th percentile[d]			
High-Risk	27.4	37.5	28.5	No	89.4	91.2	89.6

	Males 880 (89%)	Females 156 (11%)	Total 1,036		Males 880 (89%)	Females 156 (11%)	Total 1,036
High-Risk Diastolic Blood Pressure[a]				Yes	10.6	8.8	10.4
Normal	68.4	61.0	67.6	Mean (SD)	1.651 (0.103)	1.499 (0.094)	
High-Risk	31.6	39.1	32.4				
High-Risk Combined Blood Pressure[a]				*Obese*[e]			
Normal	64.7	55.1	63.6	No	98.0	91.6	97.3
High-Risk	35.3	44.9	36.4	Yes	2.0	8.4	2.7
High-Risk Waist Circumference[b]				*Index of 4 Cardiovascular Indicators*[f]			
Normal	96.7	65.4	93.1	None	54.2	27.1	51.2
High-Risk	3.3	34.6	6.9	Any	45.8	72.9	48.8
High-Risk Pulse Rate[c]				Mean (SD)	0.58 (1.156)	1.13 (1.376)	
Normal	82.8	75.1	82.0				
High-Risk	17.2	24.9	18.0				

[a] Based on the average of 3 measurements taken and adjusted for antihypertensive medication usage. High-risk blood pressure was defined as follows: systolic (≥140 mm Hg or antihypertensive medication usage), diastolic (≥ 90 mm Hg or antihypertensive medication usage), combined (systolic blood pressure ≥ 140 mm Hg or diastolic blood pressure ≥ 90 mm Hg or antihypertensive medication usage).

[b] High-risk waist circumference was defined as >102 cm for males and >88 cm for females.

[c] High-risk pulse rate was defined as ≥90 beats per minute.

[d] The 10th height percentiles are defined as ≤1.561 m for males, ≤1.426 m for females.

[e] Obesity was defined as ≥30 kg/m^2 based on measured height and weight.

[f] Indicators were: high-risk combined blood pressure, high-risk waist circumference, high-risk pulse rate, and obesity (see preceding footnotes for variable definitions).

Table 2

Odds ratios, 95% confidence intervals, and predicted probabilities from logistic regression models of the associations between negative rainfall shocks during gestation and adult hypertension and CVD index

	Model 1		Model 2		Model 1		Model 2	
	High-Risk Systolic Blood Pressure[a]				**High-Risk Combined Blood Pressure**[a]			
Negative Rainfall Shock	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Gestation	1.24^{*}	[1.04,1.49]	1.26^{*}	[1.04,1.52]	1.40^{***}	[1.17,1.68]	1.40^{***}	[1.17,1.67]
1st Trimester	1.14	[0.83,1.57]	1.25	[0.91,1.73]	1.18	[0.86,1.63]	1.27	[0.90,1.78]
2nd Trimester	1.40^{*}	[1.02,1.92]	1.34^{+}	[1.00,1.82]	1.59^{***}	[1.23,2.05]	1.46^{**}	[1.14,1.88]
3rd Trimester	1.16	[0.88,1.53]	1.17	[0.85,1.61]	1.44^{**}	[1.10,1.88]	1.47^{**}	[1.14,1.90]
Predicted Probabilities:[b]								
0 months	0.22		0.21		0.26		0.25	
1 month	0.26		0.25		0.33		0.32	
Difference with 0 months	*0.04*		*0.04*		*0.07*		*0.07*	
Mean months exposure	0.28		0.26		0.36		0.35	
Difference with 0 months	*0.05*		*0.06*		*0.10*		*0.10*	
	High-Risk Diastolic Blood Pressure[a]				**Index of 4 Cardiovascular Indicators**[c]			
Negative Rainfall Shock	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Gestation	1.33^{**}	[1.12,1.59]	1.32^{**}	[1.10,1.57]	1.39^{***}	[1.16,1.65]	1.38^{***}	[1.16,1.63]
1st Trimester	1.23	[0.91,1.66]	1.34^{+}	[0.97,1.85]	1.23	[0.90,1.69]	1.34^{+}	[0.98,1.83]
2nd Trimester	1.34^{*}	[1.05,1.73]	1.22	[0.94,1.58]	1.64^{***}	[1.25,2.16]	1.51^{**}	[1.16,1.97]
3rd Trimester	1.44^{*}	[1.08,1.92]	1.41^{*}	[1.07,1.87]	1.28^{+}	[0.98,1.66]	1.29^{+}	[0.99,1.67]
Predicted Probabilities:[b]								
0 months	0.24		0.23		0.38		0.38	
1 month	0.29		0.28		0.46		0.46	
Difference with 0 months	*0.06*		*0.05*		*0.08*		*0.08*	
Mean months exposure	0.32		0.30		0.49		0.49	
Difference with 0 months	*0.08*		*0.07*		*0.11*		*0.11*	

$^{+}$p<0.10,

[*] $p<0.05$,

[**] $p<0.01$,

[***] $p<0.001$

Note: Model 1 controls for age and sex. Model 2 controls for age, sex, season of birth, state of residence, urban/rural residence, mother's education, father's occupation, respondent's education, religion, and caste.

[a] Based on the average of 3 measurements taken and adjusted for antihypertensive medication usage. High-risk blood pressure was defined as follows: systolic (≥140 mm Hg or antihypertensive medication usage), diastolic (≥90 mm Hg or antihypertensive medication usage), combined (systolic blood pressure ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg or antihypertensive medication usage).

[b] Predicted probabilities apply to three scenarios: 0 months of exposure, 1 month of exposure, and the mean months of exposure to the shock during the 9-month gestational period. All other variables were set at their mean values.

[c] Indicators were: high-risk combined blood pressure (see footnote a for variable definition), high-risk waist circumference (>102 cm for males, >88 cm for females), high-risk pulse rate (≥90 beats per minute.), and obesity (≥30 kg/m^2 based on measured height and weight).

Table 3

Odds ratios, 95% confidence intervals, and predicted probabilities from logistic regression models of the associations between rainfall shocks during the 9-month post-birth period and adult hypertension, CVD index, and height

	Model 1		**Model 2**		**Model 1**		**Model 2**	
	High-Risk Systolic Blood Pressure[a]				**High-Risk Combined Blood Pressure**[a]			
Positive Rainfall Shock	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Post-birth Period, 9 months	1.27^{*}	[1.00,1.61]	1.21	[0.96,1.54]	1.32^{*}	[1.05,1.67]	1.29^{*}	[1.01,1.64]
0–3 Months	1.10	[0.78,1.54]	1.04	[0.70,1.53]	0.99	[0.71,1.38]	0.92	[0.63,1.35]
3–6 Months	1.53^{*}	[1.04,2.23]	1.63^{*}	[1.11,2.39]	1.65^{**}	[1.20,2.25]	1.76^{***}	[1.26,2.46]
6–9 Months	1.21	[0.75,1.97]	1.01	[0.67,1.53]	1.51^{*}	[1.03,2.22]	1.38^{+}	[0.94,2.03]
0–3 Months, Monsoon	1.24	[0.68,2.27]	1.40	[0.74,2.62]	1.06	[0.57,1.95]	1.06	[0.59,1.93]
3–6 Months, Monsoon	2.14^{**}	[1.29,3.57]	2.14^{**}	[1.24,3.68]	1.92^{*}	[1.07,3.47]	1.85^{+}	[0.99,3.46]
6–9 Months, Monsoon	0.70	[0.34,1.44]	0.48^{+}	[0.22,1.07]	1.15	[0.63,2.11]	1.10	[0.50,2.43]
Predicted Probabilities:[b]								
0 months	0.24		0.23		0.31		0.30	
1 month	0.29		0.27		0.37		0.36	
Difference with 0 months	*0.05*		*0.04*		*0.06*		*0.06*	
Mean months exposure	0.28		0.26		0.36		0.35	
Difference with 0 months	*0.04*		*0.03*		*0.05*		*0.05*	
	High-Risk Diastolic Blood Pressure[a]				**Index of 4 Cardiovascular Indicators**[c]			
Positive Rainfall Shock	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Post-birth Period, 9 months	1.26^{*}	[1.01,1.59]	1.21	[0.94,1.55]	1.23^{+}	[0.98,1.53]	1.21^{+}	[0.97,1.52]
0–3 Months	0.93	[0.67,1.29]	0.85	[0.59,1.23]	1.08	[0.71,1.63]	1.05	[0.67,1.63]
3–6 Months	1.56^{**}	[1.13,2.14]	1.63^{**}	[1.14,2.33]	1.32^{+}	[0.98,1.77]	1.40^{*}	[1.04,1.90]
6–9 Months	1.48^{+}	[0.98,2.23]	1.33	[0.86,2.06]	1.36	[0.92,2.02]	1.25	[0.86,1.81]
0–3 Months, Monsoon	1.06	[0.57,1.97]	1.11	[0.61,2.04]	1.07	[0.61,1.90]	1.03	[0.58,1.83]
3–6 Months, Monsoon	1.77^{+}	[0.93,3.33]	1.59	[0.81,3.10]	1.52	[0.84,2.77]	1.46	[0.79,2.71]
6–9 Months, Monsoon	1.06	[0.54,2.11]	0.96	[0.39,2.35]	1.16	[0.64,2.12]	1.26	[0.58,2.73]

	Model 1		Model 2		Model 1		Model 2	
	High-Risk Systolic Blood Pressure[a]				**High-Risk Combined Blood Pressure**[a]			
Positive Rainfall Shock	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Predicted Probabilities:[b]								
0 months	0.28		0.27		0.45		0.45	
1 month	0.33		0.31		0.50		0.50	
Difference with 0 months	*0.05*		*0.04*		*0.05*		*0.05*	
Mean months exposure	0.32		0.31		0.49		0.49	
Difference with 0 months	*0.04*		*0.03*		*0.04*		*0.04*	

	Height, ≤ 10th Percentile[d]			
Negative Rainfall Shock	OR	95% CI	OR	95% CI
Post-birth Period, 9 months	1.31*	[1.07,1.62]	1.39**	[1.11,1.75]
0–3 Months	1.60*	[1.06,2.43]	1.42	[0.93,2.15]
3–6 Months	1.02	[0.67,1.54]	1.07	[0.69,1.68]
6–9 Months	1.48*	[1.09,2.00]	1.68**	[1.20,2.35]
0–3 Months, Monsoon	1.45	[0.65,3.21]	1.49	[0.68,3.26]
3–6 Months, Monsoon	0.66	[0.28,1.56]	0.84	[0.32,2.23]
6–9 Months, Monsoon	2.18*	[1.07,4.41]	2.56*	[1.17,5.62]
Predicted Probabilities:[b]				
0 months	0.06		0.04	
1 month	0.08		0.06	
Difference with 0 months	*0.02*		*0.02*	
Mean months exposure	0.09		0.07	
Difference with 0 months	*0.03*		*0.03*	

$^{+}$p<0.10,

*p<0.05,

**p<0.01,

***p<0.001

Note: Model 1 controls for age and sex. Model 2 controls for age, sex, season of birth, state of residence, urban/rural residence, mother's education, father's occupation, respondent's education, religion, and caste.

[a] Based on the average of 3 measurements taken and adjusted for antihypertensive medication usage. The high-risk blood pressure measures are defined as follows: systolic (≥140 mm Hg or antihypertensive medication usage), diastolic (≥90 mm Hg or antihypertensive medication usage), combined (systolic blood pressure ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg or antihypertensive medication usage).

[b] Predicted probabilities apply to three scenarios: 0 months of exposure, 1 month of exposure, and the mean months of exposure to the shock during the 9-month post-birth period. All other variables were set at their mean values.

[c] Indicators were: high-risk combined blood pressure (see preceding footnote for variable definition), high-risk waist circumference (>102 cm for males, >88 cm for females), high-risk pulse rate (≥90 beats per minute.), and obesity (≥30 kg/m^2 based on measured height and weight).

[d] The 10th height percentiles are defined as ≤1.561 m for males, ≤1.426 m for females.

Table 4

Odds ratios, 95% confidence intervals, and predicted probabilities from logistic regression models of the associations between positive temperature shocks during the 9-month post-birth period and adult height

	Model 1		**Model 2**	
	Height, ≤ 10th Percentile[a]			
Positive Temperature Shocks	**OR**	**95% CI**	**OR**	**95% CI**
Post-birth Period, 9 months	1.22^{+}	[0.98,1.53]	1.39**	[1.11,1.73]
0–3 Months	1.27	[0.74,2.18]	1.32	[0.76,2.28]
3–6 Months	1.09	[0.58,2.06]	1.38	[0.78,2.44]
6–9 Months	1.36	[0.84,2.19]	1.48^{+}	[0.94,2.31]
0–3 Months, Summer	1.18	[0.62,2.23]	1.23	[0.58,2.63]
3–6 Months, Summer	1.12	[0.52,2.45]	1.18	[0.42,3.34]
6–9 Months, Summer	1.56	[0.80,3.05]	2.01^{+}	[0.89,4.53]
Predicted Probabilities:[b]				
0 months	0.08		0.05	
1 month	0.09		0.07	
Difference with 0 months	*0.02*		*0.02*	
Mean months exposure	0.09		0.07	
Difference with 0 months	*0.02*		*0.02*	

Note: Model 1 controls for age and sex. Model 2 controls for age, sex, season of birth, state of residence, urban/rural residence, mother's education, father's occupation, respondent's education, religion, and caste.

$^{+}$p<0.10,

*p<0.05,

**p<0.01,

***p<0.001

[a] The 10th height percentiles are defined as: ≤1.561 m for males, ≤1.426 m for females.

[b] Predicted probabilities apply to three scenarios: 0 months of exposure, 1 month of exposure, and the mean months of exposure to the shock during the 9-month post-birth period. All other variables were set at their mean values.

Table 5

Odds ratios and 95% confidence intervals from logistic regression models of the associations between rainfall shocks during the first four years after birth and adult hypertension, CVD index, and height

	Model 1		Model 2		Model 1		Model 2	
	High-Risk Systolic Blood Pressure[a]				**High-Risk Combined Blood Pressure**[a]			
Positive Rainfall Shocks	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Year 1	1.22^{*}	[1.01,1.46]	1.21^{*}	[1.01,1.46]	1.29^{**}	[1.07,1.56]	1.31^{**}	[1.08,1.60]
Year 2	1.02	[0.83,1.24]	0.93	[0.78,1.11]	1.05	[0.84,1.32]	0.97	[0.80,1.16]
Year 3	1.11	[0.91,1.36]	1.07	[0.87,1.31]	1.25^{*}	[1.03,1.52]	1.20^{+}	[0.98,1.46]
Year 4	0.98	[0.75,1.27]	0.96	[0.76,1.20]	1.04	[0.88,1.24]	1.04	[0.88,1.22]
	High-Risk Diastolic Blood Pressure[a]				**Index of 4 Cardiovascular Indicators**[b]			
Positive Rainfall Shocks	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Year 1	1.21^{*}	[1.01,1.46]	1.22^{+}	[1.00,1.49]	1.19^{+}	[0.99,1.42]	1.21^{*}	[1.01,1.46]
Year 2	1.02	[0.80,1.30]	0.92	[0.75,1.13]	1.00	[0.79,1.26]	0.94	[0.77,1.13]
Year 3	1.18^{+}	[0.97,1.44]	1.14	[0.93,1.40]	1.23^{*}	[1.00,1.50]	1.19	[0.96,1.46]
Year 4	1.03	[0.87,1.21]	1.03	[0.87,1.21]	1.04	[0.87,1.24]	1.03	[0.86,1.22]
	Height, ≤ 10th Percentile[c]							
Negative Rainfall Shocks	OR	95% CI	OR	95% CI				
Year 1	1.30^{*}	[1.04,1.63]	1.44^{***}	[1.16,1.78]				
Year 2	1.36^{**}	[1.12,1.66]	1.41^{*}	[1.08,1.84]				
Year 3	0.84	[0.67,1.04]	0.82^{+}	[0.66,1.02]				
Year 4	1.04	[0.86,1.26]	1.01	[0.82,1.23]				
Year 1, Monsoon	1.19	[0.77,1.84]	1.43	[0.92,2.22]				
Year 2, Monsoon	1.67^{*}	[1.07,2.61]	1.63^{*}	[1.02,2.63]				
Year 3, Monsoon	0.96	[0.66,1.40]	0.94	[0.63,1.39]				
Year 4, Monsoon	1.03	[0.65,1.62]	0.99	[0.62,1.59]				

$^{+}p<0.10$,

$^{*}p<0.05$,

[**] $p<0.01$,

[***] $p<0.001$

Note: Model 1 controls for age and sex. Model 2 controls for age, sex, season of birth, state of residence, urban/rural residence, mother's education, father's occupation, respondent's education, religion, and caste.

[a] Based on the average of 3 measurements taken and adjusted for antihypertensive medication usage. The high-risk blood pressure measures are defined as follows: systolic (≥140 mm Hg or antihypertensive medication usage), diastolic (≥90 mm Hg or antihypertensive medication usage), combined (systolic blood pressure ≥140 mm Hg or diastolic blood pressure ≥90 mm Hg or antihypertensive medication usage).

[b] Indicators were: high-risk combined blood pressure (see preceding footnote for variable definition), high-risk waist circumference (>102 cm for males, >88 cm for females), high-risk pulse rate (≥90 beats per minute.), and obesity (≥30 kg/m^2 based on measured height and weight).

[c] The 10th height percentiles are defined as ≤1.561 m for males, ≤1.426 m for females.

Table 6

Odds ratios and 95% confidence intervals from logistic regression models of the associations between positive temperature shocks during the first four years after birth and adult height

	Model 1		**Model 2**	
	Height, ≤ 10th Percentile[a]			
Positive Temperature Shocks	**OR**	**95% CI**	**OR**	**95% CI**
Year 1	1.37^{**}	[1.10,1.69]	1.43^{**}	[1.15,1.78]
Year 2	1.12	[0.89,1.42]	1.12	[0.89,1.42]
Year 3	1.03	[0.80,1.32]	1.03	[0.82,1.29]
Year 4	1.13	[0.97,1.32]	1.04	[0.90,1.21]
Year 1, Summer	1.41^{+}	[0.94,2.12]	1.59^{+}	[0.99,2.56]
Year 2, Summer	1.51^{+}	[0.97,2.35]	1.75^{*}	[1.13,2.71]
Year 3, Summer	0.80	[0.47,1.35]	0.88	[0.55,1.40]
Year 4, Summer	0.89	[0.61,1.29]	0.93	[0.62,1.39]

$^{+}$p<0.10,

*p<0.05,

**p<0.01,

***p<0.001

Note: Model 1 controls for age and sex. Model 2 controls for age, sex, season of birth, state of residence, urban/rural residence, mother's education, father's occupation, respondent's education, religion, and caste.

[a] The 10th height percentiles are defined as ≤1.561 m for males, ≤1.426 m for females.