**Did the 2020 COVID-19 lockdown reverse the nutritional gains in children? Evidence from primary panel data in rural India**

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**Abstract**

A growing literature has investigated the adverse effects of the COVID-19 pandemic on rising food and nutrition insecurity due to a decline in incomes, disruptions in agricultural supply chains and social safety net programs. However, the current research is not clear on the missing link that goes beyond the decline in dietary consumption to assess the impact of the pandemic on growth outcomes. Our study attempts to bridge this research gap and assess the impact of the pandemic on weight- for- age outcomes for children under five. Using the primary panel data from rural India, we find that the pandemic is associated with an average decline of 0.5 to 0.6 standard deviations of the weight-for-age z-score. The estimates are robust to varying levels of controls and fixed effects. Furthermore, our results indicate that children under two were disproportionately and more severely impacted relative to children who were 2 – 5 years old at the baseline. This is a piece of critical research as even before the pandemic, India was home to the highest number of severely acute malnourished children in the world. This study provides robust and rigorous empirical evidence that the pandemic has attributed to a worsening of child growth outcomes. Such a quantifiable estimation of the impact of COVID-19 on child nutrition status in India has significant value in developing mitigation strategies that can safeguard the nutrition security of children from future exogenous shocks such as the pandemic.

Keywords: COVID-19 pandemic, child nutrition, underweight, India, nutrition security

## 1. Introduction

The unprecedented COVID-19 pandemic has posed a grave risk to the health and nutritional status of children in low and middle-income countries. Of specific concern is the increase in rates of child malnutrition, including the prevalence of being underweight, which is expected to have increased as a result of a steep decline in household incomes, reduced access to and affordability of healthy diets, and an interruption of social security nets that provided meals, healthcare, and other nutrition-related services (Osendarp et al 2021, Headey et al 2020). In this paper we empirically examine the effects of the COVID-19 lockdown on the prevalence of underweight children (under- 5), using primary panel data collected from rural India. We hypothesize that the pandemic adversely affected the ability of households to provide nutritious foods and adequate care practices for young children and that this is expected to be reflected in a significantly higher prevalence of underweight in children under five.

Diet diversity is one of the immediate determinants of nutrition outcomes in children (UNICEF, 2020). The quality of food consumption, reflected in the intake of a diverse range of foods that provide an adequate amount of nutrients, determines eventual nutritional outcomes including, but not limited to, a healthy weight- for- age in children. Individual- level diet diversity is a function of underlying level of household food security, or in other words, factors that influence access to nutritious, affordable foods by households. A second proximal driver of child nutrition outcomes is adequate care services and practices that are in turn a function of child- appropriate feeding, hygiene, and access to health services/ interventions. Emerging evidence has indicated that underlying factors related to household food security and care services for children were adversely affected as the COVID-19 pandemic disrupted livelihoods, food systems as well as health services. We expand on this below.

### *1.1 The pandemic was associated with increasing household food insecurity*

In rural India, household food security was adversely impacted by the onset of the pandemic. On the one hand, due to the restricted movements, there was limited movement of fresh produce from farms to consumers, putting upward pressure on the prices of certain food groups (Mahajan & Tomar, 2020; Seth et al., 2020). On the other hand, these price increases occurred even as the pandemic prompted a drastic loss of livelihood and income, and resulted in a drop in purchasing power (World Bank, 2020). Figures from the Centre for Monitoring

Indian Economy (CMIE) reported that in April 2020 alone (i.e., a mere one month after the national lockdown), 122 million people lost their jobs (BBC News, 2020). Among them, 75 percent were small traders and daily wage earners. These represent the severely impoverished and marginalized subsections of India's population.

Globally, healthy diets became increasingly unaffordable during the pandemic (Laborde et al 2021). Corroborating evidence from India indicates that pandemic-induced shocks compelled households to shift away from nutrient-dense foods (like fruits, vegetable dairy, meat, and fish) towards cheaper sources of calories like starchy staples and ultra-processed foods (A. Gupta et al., 2021; A. Gupta & Kaicker, 2022; Osendarp et al., 2021, Kaicker et al 1011). This is reflected in lower expenditure on non- staples like fruits and vegetables (Kaicker et al 2022), and an overall decline in women's diet diversity scores in rural India reflected in fewer women who consumed non-staples like meats, eggs, vegetables, and fruits (Gupta et al 2021).

Although much of the evidence has shown a decline in women's diet diversity scores, to the extent that maternal diet diversity is associated with child diet diversity (Nguyen et al 2013), it is reasonable to expect that there was a corresponding decline in the quality of children's diets, post- pandemic. Overall then, it is expected that the pandemic-associated increase in food and nutrition insecurity wil have negative implications for the quality of children's diets, and that in turn is expected to result in an increased risk of child undernutrition globally (Nguyen et al., 2021; Osendarp et al., 2021) [1].

### *1.2 The pandemic was associated with interruptions to health, nutrition, and social protection services*

In a national crisis like COVID-19, it is the government's social protection programs that can ameliorate the disruptions to the supply chain and ensure food security for its citizens. In the case of India however these protection programs were also impacted by the lockdown, thereby contributing to increasing nutrition insecurity. For instance, the Integrated Child Development Services (ICDS) program runs two major nationwide programs: take-home rations (THR) (given to children aged 3 and 6) and hot cooked meals (HCM) (given to pregnant and lactating mothers, and children between 6 months and 3 years old). Following the

[1] Early estimates suggested that the pandemic- induced increasing in wasting and stunting in children under five would increase by 6.2 million and 790,000 children respectively, in South Asia alone (Osendarp et al 2021).

lockdown, there was a closure of ICDS centers. This resulted in a halting of HCM entirely, and partial, state- specific operations related to THR (Nguyen et al., 2021). Another example of a food- based safety net is the Mid-Day Meal Scheme (MDMS) which provides one nutritious meal to primary- level school children attending government schools. This too was stopped following the closure of schools during the pandemic.

At the same time utilization of maternal and child health services was also less, given the pandemic- induced travel restrictions and a preference to avoid face to face meetings with frontline workers (Nguyen et al 2021). Although such food and health service provision improved in the second half of 2020, it did not recover to pre- pandemic levels across the country (Avula et al 2022). Such disruptions to food, basic maternal and child-care services are predicted to significantly compromise the physical and cognitive development for children under the age of 2 (Victora et al., 2010).

In contrast to the ICDS and MDMS, India's Public Distribution System (PDS) was infact expanded following the onset of the pandemic. The PDS is a government-run program in India that provides essential food grains, and other basic necessities to the poor and economically disadvantaged sections of society at subsidized rates. The Indian government took several measures to ensure that the PDS system continued to function effectively and that people received benefits without any interruption, during the pandemic. The Indian government announced a relief package of in March 2020, which included measures such as distributing free food grains (rice, wheat), pulses, and cooking gas cylinders to vulnerable sections of society. The government also increased the quota of food grains and other essential commodities provided under the PDS system to ensure that people did not face any shortages. It is expected that this expansion of rations through the PDS helped maintained calorie security for households during the pandemic, even though nutrition- security is likely to have worsened (Gupta et al 2021).

Taken together, the disruptions to livelihoods, food supply chains, and safety nets not only led to an enhanced food and nutrition insecurity situation among households but are expected to subsequently exacerbate the prevalence of undernutrition among children in India. While research studies have thoroughly investigated the impact of the pandemic on the former, there is little quantitative evidence on the nature and magnitude of the effect of the lockdown on the nutritional status of the most vulnerable demography of children.

This study is well-placed to assess the impact of pandemic-induced lockdown on child undernutrition (specifically, underweight outcome). Children's weight- for- age is sensitive to short-term shocks to income and diet quality (Arndt et al., 2016). Therefore we expect this variable to accurately reflect the shock of the pandemic on children's underweight status. A study based on the potential weight loss due to the pandemic-induced immediate food shocks in India suggests that even if children were to experience a mere 0.5% (or 5%) weight loss, it would lead to an increase of about 400,000 (or 4.4 million) additional underweight children in India (Rajpal et al., 2020). To the best of our knowledge, we are not aware of similar studies that have assessed the impact of an exogenous shock like the pandemic on the prevalence of underweight children, using primary panel data in rural India. Focusing on child undernutrition like low weight-for-age has implications for economic productivity due to the longer-term impact of early childhood malnutrition, including the risk of child mortality and lost years of schooling (Martorell, 2017).

Our results indicate that the pandemic is associated with an increase of 0.5 to 0.6 standard deviations increase in the child weight- for- age z scores (WAZ scores) and a 14% increase in the prevalence of underweight children, post-pandemic. Furthermore, children below the age of 2 saw a greater decline in WAZ scores associated with the pandemic, relative to children 2 – 5 years old. Such quantifiable evidence is important to understand the magnitude of the problem that the pandemic has created. Given that, even pre-pandemic India was host to the world's highest number of children with severe acute malnutrition and researchers claim that this number of malnourished children would have increased post-pandemic, it is critical to be informed about the magnitude of these numbers after an unprecedented nutritional shock (Osendarp et al., 2021; Rajpal et al., 2020; UNICEF, 2022). Findings from this study are expected to assume salience for policymakers and program implementers, alike for designing evidence-based policies that can restore the nutritional health of children belonging to poor and marginalized households during future pandemics like COVID-19.

This study is structured as follows. Section 2 discusses the data and methods used in the paper. Section 3 presents the results. Section 4 discusses the contributions and concludes with policy implications.

## 2. Data and Methods

### *2.1 Data*

The study uses primary panel data collected from three districts Munger (Bihar) and Kandhamal and Kalahandi (Odisha) as part of the Technical Assistance and Research in Indian Nutrition and Agriculture (TARINA) program, which was led by the Tata-Cornell Institute for Agriculture and Nutrition, Cornell University with the objective of promoting nutrition-sensitive food systems in India.

The TARINA baseline and endline surveys were conducted in June 2017 (pre-COVID-19) and July 2021 (about one year and four months post the COVID-19-induced national lockdown, and at the onset of the second/ delta wave) respectively. A total of 3600 households across 120 villages in the four program districts were surveyed, in each survey round. Villages in each district were selected based on probability proportional to sample size, and households within each village were sampled randomly using village- level household lists. The TARINA surveys collected detailed information on agricultural practices, women's empowerment, household access to food, food intake, and water and sanitation-related behavior. Additionally, height and weight were recorded for the index woman and her children. At baseline, children who were five years or under were surveyed for anthropometry. These children were then followed up at endline. Children who were four or five years old at baseline would be above five years at endline. Both rounds of the survey were approved by the Institutional Review Board at Cornell University and informed consent from an index man and woman in each household was recorded electronically.

Of the 3600 original households surveyed at baseline, 3005 were resurveyed during the endline. We used this sample of 3005 households to form a panel of households for which data was collected in both survey rounds. Furthermore, across these 3005 households, we had a panel 558 households from which 675 children were surveyed in both rounds. Since there was a lower response rate for the UP district, we exclude the UP sample from the present analysis. Therefore, from the original panel of 558 households and 675 children, we retain the subsample for Bihar and Odisha only. This is equivalent to 511 households and 622 children.

### *2.2 Empirical Strategy*

We use data on the weights of children using the two TARINA surveys conducted in June 2017 and July 2021. Our dependent variable of interest is the child's weight for a given age. This is studied in terms of a weight-for-age z score (WAZ score). The WAZ score tells us the distance of a child's weight, in terms of standard deviations, from the average weight of healthy children in a reference population of the same sex and age in months.[2]

A child with a weight-for-age z-score of zero will have the same body weight as the median child in the reference group with the same age and gender. Likewise, a child with a negative WAZ score will have a lesser weight than the average weight of the reference population. A child is classified as being underweight if his/her WAZ score is two standard deviations below that of the reference group. A normal nutritional status is identified in terms of Z scores that are – 2 standard deviations or greater. Hence, a child's underweight status is a measure of nutritional failure. We follow the recommendations of the WHO's 2006 international reference population and omit children who fall beyond minus six and above five standard deviations from the mean (WHO, 2006).

To examine the main impact of the pandemic, we begin by focusing on the overall change in the WAZ scores pre-pandemic (June 2017) and post-pandemic (July 2021). Hence, our key independent variable is a binary indicator for the survey round: 0 for pre-pandemic and 1 for post-pandemic. This is referred to as $\textit{Post- Pandemic}_t$ in the equation below. Applying the fixed-effects identification strategy, we estimate the following regression-

$$WAZ_{ihvt} = \beta_0 + \beta_1 \, Post - Pandemic_t + \beta_2 \, \text{Female Child Dummy}_{ihvt} + \beta_3 \, \text{BMI Mother}_{ihvt} + \beta_4 \, \text{H}_{hvt} + \beta_5 \, OD\ Village_{vt} + A_v + \varepsilon_{ivt}$$

where *i* indexes individual children, *h* is for their household, *v* is the village area where the child resides and *t* stands for survey round. We further include additional sets of control variables in stages, in order to illustrate the robustness of our regression specifications and the stability in the magnitude of our outcome of interest.

Female Child Dummy is a binary indicator for female children.

[2] $Z - Score = \frac{\text{Measured weight – Average weight for a reference age group}}{\text{Standard deviation of weight for reference age group}}$

Mother's BMI ($\text{BMI Mother}_{ihvt}$) is included to account for the heterogeneity in maternal nutrition, and to control for any possible direct effect of mother's size on child's weight (Ounsted et al., 1986).

**H** is a vector of household-level characteristics that can influence child nutritional outcomes. It includes household's access to social safety nets both pre- and post-pandemic. Although the PDS continued to provide staple cereals during the lockdown, interruptions in the provision of cooked meals provided as part of the ICDS and MDM programs have been well documented in various parts of India (Nguyen et al 2021, Gupta et al 2021). To measure the association of social safety nets on children's WAZ scores, we construct a binary variable that was assigned the value of 1 if any household member had access to benefits from PDS, ICDS centers, THR packets from ICDS centers, mid-day meals at the government school, and any other government-assisted programs in the last one month. The variable took the value of 0 if any household member did not have access to any of the above-menitoned programs.

Additionally, we account for the role that production diversity could have played in combatting undernutrition and low dietary diversity (Sibhatu & Qaim, 2018). For this we include a categorical measure of household production diversity derived as the sum of four binary indicators that reflect the diversity of production activities – whether or not the household cultivated pulses in the previous season, cultivated vegetables in the previous season, own a kitchen garden, and owns livestock. Hence. the score ranges from 0 (no to all four variables) to 4 (yes to all four variables), with 4 signifying highest household-level production diversity. To account for household access to food we also control for monthly food expenditure on cereals and non-cereals in INR. Finally, we also account for the religion of the household head.

At the village level, we control for village-level open defecation (OD) rate that can influence child anthropometric outcomes. Village-level OD ($OD\ Village_{vt}$) is constructed as the fraction of households practicing OD. It is a continuous variable ranging from 0 to 1, with 1 (0) standing for all (no) households practicing OD in a given village. Even if the household uses toilets, fecal pathogens emanating from the neighbor's practice of OD can impose negative externalities in the form of infectious diseases, and potentially lead to a worsening of the child's nutritional status (Hammer & Spears, 2016).

$A_v$ village fixed effects are included to control for geographic heterogeneity across the villages. Standard errors are clustered at the village level, and with 120 clusters we are well-placed for asymptotic clustered standard errors (Cameron et al., 2008).

We further analyze the heterogenous impact of COVID-19 based on the age of the child i.e. children below and above two years of age at the baseline. It is well-established that younger children have less developed immune systems and hence are more likely to develop infections and become more malnourished (Victora et al., 2010). Our choice of cut-off of 24 months for the sub-group analysis is apt as growth faltering (i.e. slower development in weights and heights than what is expected in a child of a particular age and gender) occurs more predominantly in children below 24 months of age (Victora et al., 2010).

We also conduct a sub-analysis of results for the different study states. This information is useful as data from the most recent round of the National Family Health Survey (2019-21) informs us about the heterogeneity in the prevalence and risk of nutritional failures. For instance, there are 41% and 30% underweight (an indicator of recent weight loss) children in Bihar and Odisha[3]. Of these children, nearly 48% and 43% belong to the poorest households (bottom 20% of the wealth quintiles) in Bihar and Odisha, respectively. Hence, the added advantage of using this survey data is that since these households belong to the rural areas from two of the most rural states of India, information from this survey can inform us how the most marginalized regions and populations fared with regard to undernutrition outcomes during the pandemic.

Finally, we replicate the analysis using a dichotomous indicator -underweight (i.e. WAZ score < -2)- as a dependent variable. Prevalence of underweight children, i.e., the fraction of underweight children among the total child population is the most widely used nutrition-related metric for developing health and nutrition policies worldwide (Rajpal et al., 2020). Switching from a continuous to a dichotomous variable entails a loss of statistical power, however this step will demonstrate the robustness of the results (Royston et al., 2006).

[3] https://pib.gov.in/PressReleasePage.aspx?PRID=1806601

## 3. Results

### *3.1 Descriptive Statistics*

Table 1 reports that there was a significant decline of 0.52 in mean WAZ scores from baseline to endline or pre- to post-pandemic. The prevalence of underweight children also increased by 14 percentage points over the same period. These numbers vary by children's age and state of residence. Younger children witnessed a statistically significant decline in WAZ scores and a rise in the underweight prevalent rates post-pandemic.

Detailing the determinants of nutritional status, table 1 reports a mixed picture of improvement in these factors from pre- to post-pandemic. For instance, mother's BMI improved (albeit by a small magnitude). Nearly 35% more households had access to food from government's public distribution system (PDS) program by the endline, as opposed to decline of 6%, 35% 13%, and 31% in households having access to food from ICDS centers, take-home rations (THR), mid-day meals (MDMs), and any other government program, respectively.

The household's production diversity as measured through the production of pulses, vegetables, and ownership of kitchen gardens improved by 3, 3, and 7 percentage points, respectively, relative to the baseline.

The average household expenditure on both cereals and non-cereals fell, post- pandemic, with the decline being larger and more significant in the case of the latter. At the village level, there was a significant reduction of 27 percentage points of households practicing OD.

**Table 1: Nutrition Outcome and Determinants of Nutrition for Children Pre- and Post-Pandemic**

| **Characteristics** | **Baseline (Pre-pandemic) Jun-17** | **Endline (Post-pandemic) Jul-20** | **Difference** |
|---|---|---|---|
| ***Outcome: Mean WAZ Score*** | | | |
| All sample | -1.35 | -1.87 | -0.52**** |
| Children Aged 0-24 months in the baseline | -1.03 | -1.86 | -0.83**** |
| Children Aged 24-60 months in the baseline | -1.54 | -1.87 | -0.33**** |
| Bihar | -1.41 | -1.93 | -0.53*** |

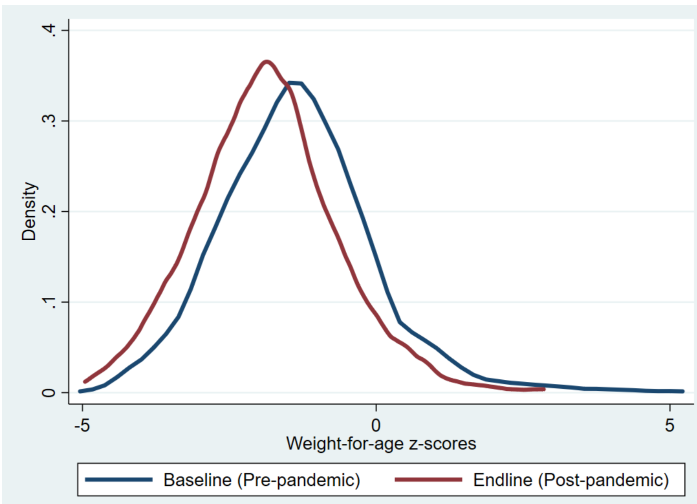
| | | | |
|---|---|---|---|
| Odisha | -1.3 | -1.81 | -0.52*** |
| ***Outcome: Underweight (WAZ < -2)*** | | | |
| All sample | 0.31 | 0.45 | 0.14**** |
| Children Aged 0-24 months in the baseline | 0.23 | 0.47 | 0.24**** |
| Children Aged 24-60 months in the baseline | 0.35 | 0.44 | 0.09** |
| Bihar | 0.33 | 0.48 | 0.15**** |
| Odisha | 0.29 | 0.43 | 0.14**** |
| ***Other Child Characteristics*** | | | |
| Female Children (%) | 0.48 | 0.47 | -0.01 |
| Age (months) | 30.2 | 76.74 | 46.54**** |
| Height (cms) | 85.95 | 107.7 | 22.14**** |
| ***Maternal Indicators*** | | | |
| Mother's BMI (normal BMI range: 18.5 to 24.9) | 20.01 | 20.81 | 0.80**** |
| ***Household Indicators*** | | | |
| % households with access to public distribution system (PDS) | 0.5 | 0.85 | 0.35**** |
| % households with access to ICDS centers | 0.37 | 0.3 | -0.06** |
| % households with access to take-home ration | 0.62 | 0.26 | -0.35**** |
| % households with access to mid-day meals | 0.6 | 0.47 | -0.13**** |
| % households with access to any other government food program | 0.37 | 0.06 | -0.31**** |
| % of households that produced pulses | 0.14 | 0.16 | 0.03 |
| % of households that produced vegetables | 0.03 | 0.06 | 0.03** |
| % of households that own kitchen garden | 0.11 | 0.19 | 0.07**** |
| % of households that own livestock | 0.44 | 0.43 | -0.003 |
| Average household expenditure on cereals (Rs) | 769.95 | 772.43 | 2.47 |

| | | | |
|---|---|---|---|
| Average household expenditure on non-cereals (Rs) | 4369.96 | 1990.27 | -2379.69**** |
| ***Village Indicators*** | | | |
| % households practicing open defecation | 0.78 | 0.5 | -0.27**** |
| Number of children | 622 | 622 | |

****p< 0.001, ***p<0.01, **p<0.05, *p<0.1

The decline in WAZ scores can be analysed in Figure 1. The kernel density estimate of the WAZ score for the sample from each survey round demonstrates that the WAZ score curve shifted to the left, post-pandemic, indicating that WAZ scores for all ages were lower at the endline as compared to baseline. Furthermore, there was a constriction in the right tail. Therefore, most of the shift or worsening of the WAZ scores post-pandemic happened for children who were already to the left along the borderline of the zero WAZ score.[4] This result is consistent with the research which predicts that children who are concentrated around the z-score cut-off of zero are more vulnerable to becoming underweight due to dietary shocks (Rajpal et al., 2020).

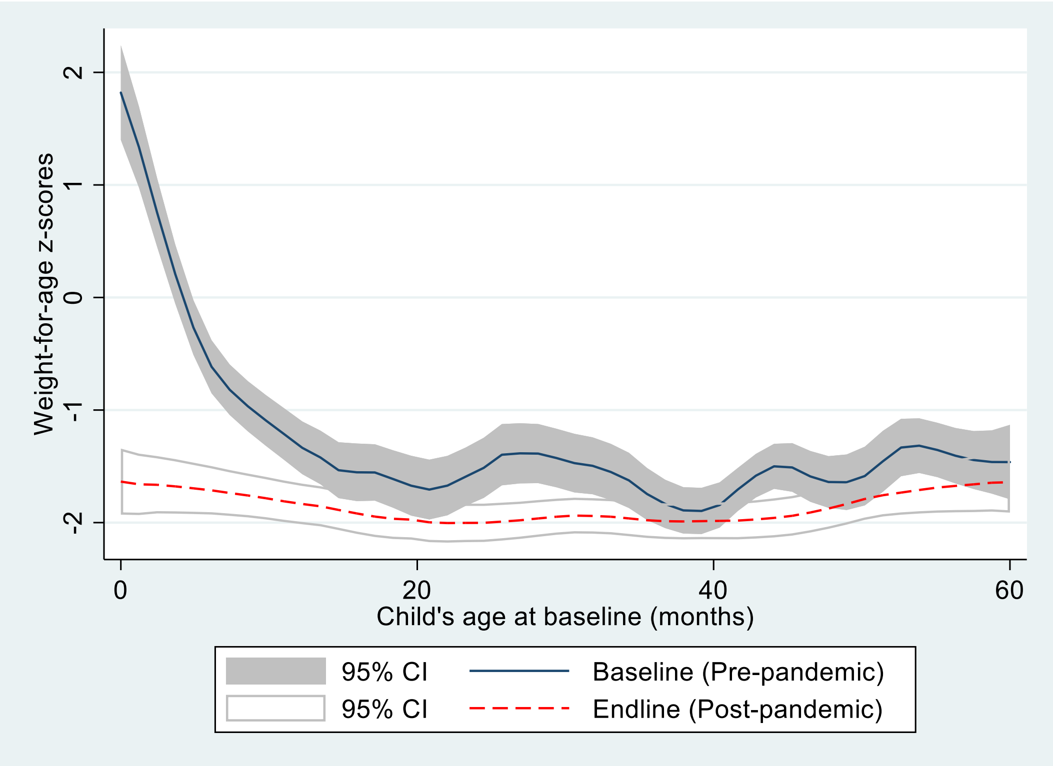
**Figure 1: Distribution of Weight-for-age z-scores from pre- to post-pandemic**




[4] A WAZ score of zero means that the weight of the child is consistent with the weight of the ideal child and conforms to the norm. A WAZ below zero means that the child is below the norm for the respective age and gender.

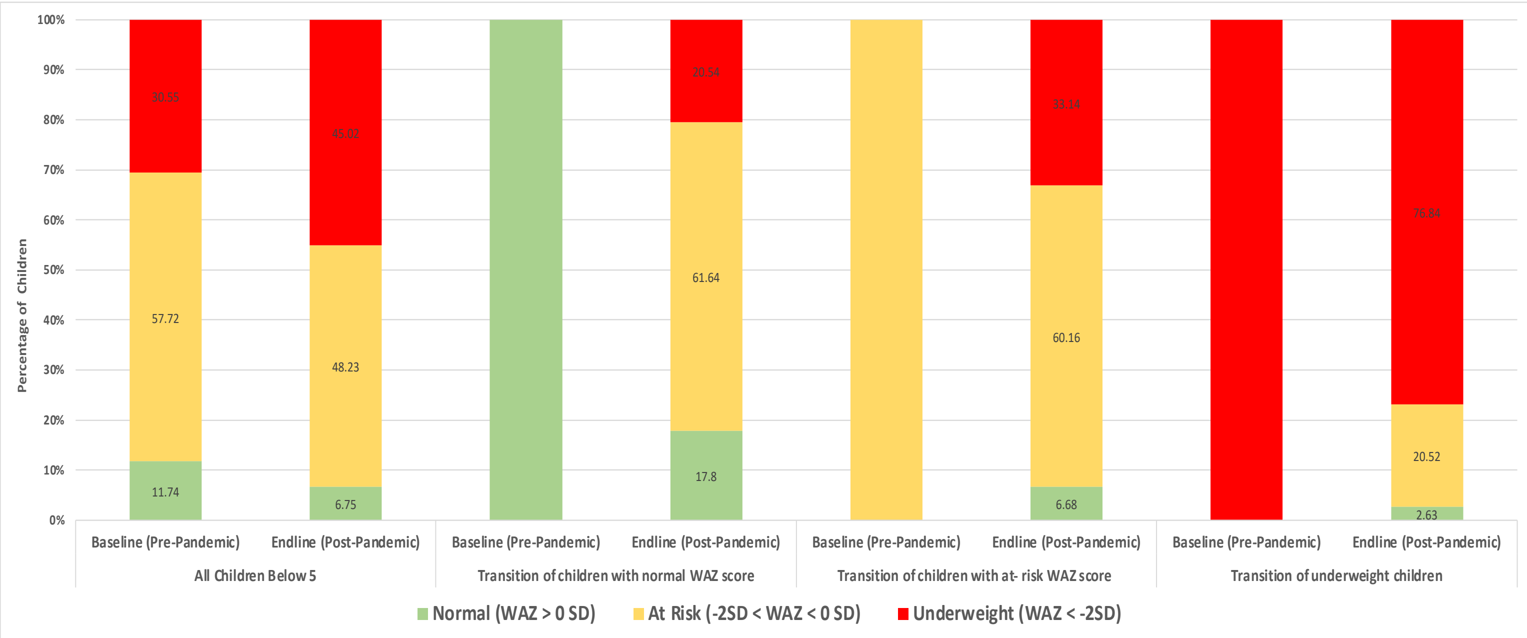
Figure 2 presents the presents local polynomial regressions that demonstrate that movement in WAZ scores along the age distribution, with separate plots for pre- and post-pandemic. The scores are plotted *using the child's age at baseline as the reference*, allowing us to compare the WAZ scores for the same child at baseline and endline. We note that the children report worse WAZ scores post-pandemic as is reflected in the relatively lower curve for endline compared to baseline.

**Figure 2: Weight-for-age z-scores by child's age in months, pre- and post-pandemic**




Next, we focus on how the severity of underweight changed between the baseline and endline. We use WAZ scores and classify children as normal (WAZ >= 0), at-risk (0<WAZ< -2 SD), or underweight (WAZ =< -2SD). At baseline, about 11% of children had a normal WAZ score with about 58% being at risk for underweight and 31% being classified as underweight (see figure 3). At endline, we find that children shifted from the normal and at-risk groups into the underweight category with 45% of children being underweight. This increase in the proportion of underweight children is arising from all three groups. Of the 11% of normal children in the baseline, 20% became underweight in the endline. In the second group, i.e. out of the 58% of the children who were at-risk in baseline, 33% of all those transitioned to being underweight in the endline. The third group consists of those children who were underweight at baseline and continued to remain so at endline, i.e., out of the 30% underweight children in the baseline, 77% continued being underweight in the endline as well.

**Figure 3: Transition of the prevalence of normal, at-risk and underweight children from baseline to endline**




*3.2 Regression evidence: Changes in weight-for-age z-scores due to the pandemic:*

In Table 2 we look at the association of various individual, household, and community- level factors with child WAZ scores. Column 1 in Table 2 simply reports the average fall of 0.52 standard deviation in child WAZ scores from pre- to post-pandemic. But could this fall be accounted for by controlling for other relevant variables that influence WAZ scores? To test for this, we progressively add maternal, household, and village-level controls in subsequent columns. When we introduce mother's BMI in column 2, we note that unsurprisingly mother's BMI significantly predicts child's WAZ scores. Adding the household-level controls in column 3, we note that the production diversity is positively and significantly associated with the WAZ scores, indicating that the impact of the pandemic on child undernutrition could have been cushioned by production diversity at home. Adding village-level controls in column 4, we see that the despite the addition of the village-level open defecation, the pandemic binary indicator was unaffected and it continutes to predict child's WAZ scores.

Taken together, these results demonstrate that the COVID-19 pandemic was linearly associated with a statistically significant decline in children's weight-for-age of around 0.5-0.6 standard deviations, using fixed effects and varying sets of controls.

**Table 2: Relationship between COVID-19 pandemic and child WAZ scores**

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Post-pandemic binary indicator | -0.52*** | -0.58*** | -0.54*** | -0.59*** |
| | (0.06) | (0.06) | (0.07) | (0.08) |
| Mother's BMI | | 0.07*** | 0.07*** | 0.07*** |
| | | (0.02) | (0.02) | (0.02) |
| Access to food- based safety nets | | | -0.16 | -0.16 |
| | | | (0.15) | (0.15) |
| Household production diversity | | | 0.11** | 0.11** |
| | | | (0.05) | (0.05) |
| Monthly household expenditure on cereals | | | -0.01 | -0.01 |
| | | | (0.01) | (0.01) |
| Monthly household expenditure on non-cereals | | | 0.07 | 0.07 |
| | | | (0.06) | (0.06) |
| Village- level open defecation rate | | | | -0.22 |
| | | | | (0.21) |
| Control for religion | | | Yes | Yes |
| Female child dummy | Yes | Yes | Yes | Yes |
| Village fixed effects | Yes | Yes | Yes | Yes |
| Observations | 1244 | 1244 | 1244 | 1244 |

*Notes*: Access to food-based safety nets refers to whether or not the household accessed food from PDS, ICDS, THR MDM, or any other government program. Household production diversity refers to whether or not the household cultivated pulses, vegetables, owns kitchen garden, owns livestock. It ranges from 0 to 4. Food expenditures are in log terms. Village- level open defecation rate refers to the proportion of households practicing open defecation in the village. The standard errors are clustered at the village level. + p<0.15, * p<0.10, ** p<0.05, *** p<.01

### *3.3 Sub-sample regression analysis: Children less than 2 years and between 2-5 years*

Literature informs us that child's age is a crucial determinant of undernutrition as children are more susceptible to infections in the first two years of life (Victora et al., 2010). We further explore the validity of these results by focusing on the association between the pandemic and WAZ scores for two groups of children: below 2 and 2 -5 years old.

Table 3 shows the heterogeneous impact of the pandemic on children's age groups. Even after controlling for relevant and varying sets of controls and fixed effects, the children below two years of age at baseline lost a statistically significant 0.83 to 0.98 standard deviations of the WAZ score, relative to smaller (but still significant) impact (0.33 to 0.39 standard deviations of the WAZ score) for the children above two years of age at the baseline, post-pandemic. Therefore, in line with the other seminal studies we show that the younger child population is more vulnerable to nutrition shocks and this age-sensitive issue needs to be dealt with more aggressively to ensure healthier children in the future (Victora et al., 2010).

In addition to the pandemic variable, maternal BMI is associated with a significant improvement in WAZ for children belonging to both age sub-groups. Production diversity is a significant driver of WAZ for children 24 – 60 months. This can presumably because that is the age group when children are consuming more of solid foods, relative to the younger age group (below 24 months).

**Table 3: Relationship between COVID-19 pandemic and WAZ scores, by child age**

| | Children aged 0-24 months at baseline | | | | Children aged 24-60 months at baseline | | | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (1) | (2) | (3) | (4) |
| Post-pandemic binary indicator | -0.83*** | -0.88*** | -0.84*** | -0.98*** | -0.33*** | -0.39*** | -0.37*** | -0.39*** |
| | (0.1) | (0.1) | (0.12) | (0.13) | (0.08) | (0.08) | (0.11) | (0.11) |
| Mother's BMI | | 0.06* | 0.05* | 0.05* | | 0.08*** | 0.08*** | 0.08*** |
| | | (0.03) | (0.03) | (0.03) | | (0.02) | (0.02) | (0.02) |
| Access to food- based safety nets | | | -0.14 | -0.14 | | | -0.06 | -0.06 |
| | | | (0.28) | (0.28) | | | (0.17) | (0.17) |
| Household production diversity | | | -0.02 | -0.01 | | | 0.12+ | 0.12+ |
| | | | (0.11) | (0.11) | | | (0.07) | (0.07) |
| Monthly household expenditure on cereals | | | -0.02 | -0.02 | | | -0.01 | -0.01 |
| | | | (0.03) | (0.03) | | | (0.02) | (0.02) |
| Monthly household expenditure on non-cereals | | | 0.08 | 0.09 | | | 0.04 | 0.05 |
| | | | (0.11) | (0.11) | | | (0.08) | (0.08) |
| Village- level open defecation rate | | | | -0.48+ | | | | -0.08 |
| | | | | (0.3) | | | | (0.27) |
| Control for religion | | | Yes | Yes | | | Yes | Yes |
| Female child dummy | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Village fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 482 | 482 | 482 | 482 | 760 | 760 | 760 | 760 |

*Notes*: Access to food-based safety nets refers to whether or not the household accessed food from PDS, ICDS, THR MDM, or any other government program. Household production diversity refers to whether or not the household cultivated pulses, vegetables, owns kitchen garden, owns livestock. It ranges from 0 to 4. Food expenditures are in log terms. Village- level open defecation rate refers to the proportion of households practicing open defecation in the village. The standard errors are clustered at the village level. + p<0.15, * p<0.10, ** p<0.05, *** p<.01

### *3.4 Sub-sample regression analysis by state*

We further analyze the decline in children's WAZ scores during the pandemic by states in Table 4. We find a statistically significant decline in child WAZ scores in both states post-pandemic as compared to baseline. The average decline in child WAZ scores was the same for Bihar and Odisha (about 0.6 SD). Unlike Bihar, production diversity was associated with improvements in WAZ scores in Odisha. Our result is in line with the research that also predicts that in the face of shocks to nutrition security, Bihar is one of the states that is expected to account for the highest share of projected additional underweight children among the poorest households (Rajpal et al., 2020).

**Table 4: Relationship between COVID-19 pandemic and WAZ scores, by state**

| | Bihar | Odisha |
|---|---|---|
| Post-pandemic binary indicator | -0.60*** | -0.60*** |
| | (0.08) | (0.18) |
| Mother's BMI | 0.06*** | 0.07*** |
| | (0.02) | (0.03) |
| Access to food- based safety nets | -0.14 | -0.26 |
| | (0.17) | (0.37) |
| Household production diversity | 0.09 | 0.14+ |
| | (0.07) | (0.09) |
| Monthly household expenditure on cereals | -0.01 | 0 |
| | (0.02) | (0.02) |
| Monthly household expenditure on non-cereals | 0.03 | 0.11 |
| | (0.08) | (0.09) |
| Village- level open defecation rate | -0.28 | -0.3 |
| | (0.43) | (0.3) |
| Control for religion | Yes | Yes |
| Female child dummy | Yes | Yes |
| Village fixed effects | Yes | Yes |
| Observations | 560 | 684 |

*Notes*: Access to food-based safety nets refers to whether or not the household accessed food from PDS, ICDS, THR  MDM, or any other government program. Household production diversity refers to whether or not the household cultivated pulses, vegetables, owns kitchen garden, owns livestock. It ranges from 0 to 4. Food expenditures are in log terms. Village- level open defecation rate refers to the proportion of households practicing open defecation in the village. The standard errors are clustered at the village level. + p<0.15, * p<0.10, ** p<0.05, *** p<.01

### *3.4 Robustness check: Using prevalence of underweight as an alternate dependent variable*

As discussed before, the use of binary outcomes is discouraged as it entails a loss of statistical power and wider confidence intervals (Royston et al., 2006). That is why we used a continuous measure (WAZ scores) as our primary analysis. However, for a more comprehensive analysis and robustness check, we use underweight (defined as the share of children with WAZ < -2) as our dependent variable.

We repeat the analysis of Table 2 to determine the association between the pandemic variable and prevalence of underweight among children. As depicted in Table 5, the pandemic is associated with a significant increase of 13 to 16 percentage points increase in the prevalence of underweight children. The results exhibit resilience of our outcome measure and the strong impact of the pandemic on children's weights (whether measured as a continuous outcome variable (WAZ scores)) or a binary indicator (underweight prevalence)). At the same time, prevalence of underweight reduces with improvements in household production diversity as well as with increasing expenditure on non- staples.

**Table 5: COVID-19 pandemic and prevalence of underweight in children**

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| Post-pandemic binary indicator | 0.14*** | 0.16*** | 0.14*** | 0.13*** |
| | (0.02) | (0.02) | (0.03) | (0.03) |
| Mother's BMI | | -0.02*** | -0.02*** | -0.02*** |
| | | (0.01) | (0.01) | (0.01) |
| Access to food- based safety nets | | | -0.01 | -0.01 |
| | | | (0.05) | (0.05) |
| Household production diversity | | | -0.05** | -0.05** |

| | | | | |
|---|---|---|---|---|
| | | | (0.02) | (0.02) |
| Monthly household expenditure on cereals | | | 0 | 0 |
| | | | (0.01) | (0.01) |
| Monthly household expenditure on non-cereals | | | -0.04+ | -0.04+ |
| | | | (0.02) | (0.02) |
| Village- level open defecation rate | | | | -0.01 |
| | | | | (0.09) |
| Control for religion | | | Yes | Yes |
| Female child dummy | Yes | Yes | Yes | Yes |
| Village fixed effects | Yes | Yes | Yes | Yes |
| Observations | 1244 | 1244 | 1244 | 1244 |

*Notes*: Access to food-based safety nets refers to whether or not the household accessed food from PDS, ICDS, THR MDM, or any other government program. Household production diversity refers to whether or not the household cultivated pulses, vegetables, owns kitchen garden, owns livestock. It ranges from 0 to 4. Food expenditures are in log terms. Village- level open defecation rate refers to the proportion of households practicing open defecation in the village. The standard errors are clustered at the village level. + p<0.15, * p<0.10, ** p<0.05, *** p<.01

## 4. Discussion and Policy Implications

In this body of work we study the relationship between the COVID-19 pandemic and the prevalence of underweight in children using primary panel data collected in rural India. While rigorous research studies have successfully exhibited the adverse impact of the pandemic on food security (S. Gupta et al., 2021; Kaicker et al., 2022), there is a missing link that goes beyond dietary intake and food expenditures to look at its consequent impact on anthropometry. This analysis bridges this crucial research gap. Our findings suggest the COVID-19 pandemic-induced lockdown is significantly associated with the worsening of weight-for-age z-scores (from -1.35 to -1.87) or an increase in the prevalence of underweight children (from 31% to 45%) in our sample from rural India. We find that the binary indicator to demarcate the onset of the pandemic is robustly associated with a significant worsening of child WAZ in all specifications after controlling for confounding maternal, household and village- level factors.

This quantifiable evidence of COVID-19 on children's WAZ scores from panel data in rural India contributes to an emerging evidence base on how child anthropometric outcomes were affected during the pandemic. These results can inform the design of mitigation strategies for overcoming the short and medium-term adverse nutritional effects and safeguarding children from future nutritional shocks. Future policymakers and program implementers should undertake interventions to ensure an uninterrupted supply of nutritious meals and food supplements to the vulnerable demography of children while impeding the spread of infection.

One strategy to ensure access to diverse, nutritious foods is by incentivizing the diversification of agricultural production in the country. Our results indicate that a significant predictor of WAZ scores is household production diversity, especially in Odisha. Household production diversity has been associated with higher consumption diversity in various settings, pre-pandemic (S. Gupta et al., 2020). More recently, research has found that the farmers who cultivated 2-3 more crops were significantly less likely to experience a decline in dietary diversity during the pandemic across 12 states in India (Connors et al., 2021). This suggests that households with greater production diversity were likely to be more resilient to the market disruption and economic impact of the pandemic, leading to better child nutrition. Hence, even though literature has often asserted a small role between production and dietary diversity, there should be a higher emphasis on promoting these systems as their importance increases during global pandemics (Connors et al., 2021; Sibhatu & Qaim, 2018).

In addition to their own production, households in rural India rely on food-based safety nets that provide cooked meals and/ or take-home rations to vulnerable groups like young children and pregnant and lactating mothers. Recent evidence points to an increase in anemia among rural primary-school children, aged 6–12 years, due to the closure of MDMs, and subsequent lower dietary diversity in Karnataka (Thankachan, et al. 2022). Therefore, minimal disruptions to the receipt of benefits from the ICDS centers or other social services programs should be the top priority as it has successfully ensured supplementary nutrition to the most vulnerable demographics of children and women belonging to marginalized households. The state governments could also explore the benefits of switching to direct cash benefits transfer to needy households in case of a scenario like a pandemic when physical delivery of benefits becomes difficult.

Besides this, restoration of basic maternal and child-care health services will be critical to alleviating any loss in health due to the non-receipt of these services during the pandemic. Our results reiterate the importance of maternal health for child health outcomes. Mothers' BMI is associated with a significant improvement in WAZ scores for the total sample and for all of our subgroup analyses. We note that there was a small, but significant increase in women's BMI during the study period. This effect could imply that women were more anthropometrically secure than children, or that their body weights were quick to recover from pandemic- related shocks relative to children.

This study is not without its limitations. The post-pandemic analysis is restricted to only weight-for-age z-scores as an outcome variable, which is immediately influenced by changes in the quantity and quality of diets. Future research papers can assess the long-term impact of the pandemic on the prevalence of child stunting (low height-for-height) and wasting (low weight-for-height). Moreover, since the analysis of this paper was constrained to three districts in India, evaluating the external validity of the study could be a starting point for the researchers as they look at possible reversal of nutritional gains made in different regions of India.

**References**


Arndt, C., Hussain, M. A., Salvucci, V., & Østerdal, L. P. (2016). Effects of food price shocks on child malnutrition: The Mozambican experience 2008/2009. *Economics & Human Biology*, *22*, 1–13. https://doi.org/10.1016/j.ehb.2016.03.003

BBC News. (2020, May 6). Coronavirus lockdown: India jobless numbers cross 120 million in April. *BBC News*. https://www.bbc.com/news/world-asia-india-52559324

Cameron, A. C., Gelbach, J. B., & Miller, D. L. (2008). Bootstrap-based improvements for inference with clustered errors. *The Review of Economics and Statistics*, *90*(3), 414–427.

Connors, K., Jaacks, L. M., Prabhakaran, P., Veluguri, D., Ramanjaneyulu, G. V., & Roy, A. (2021). Impact of Crop Diversity on Dietary Diversity Among Farmers in India During the COVID-19 Pandemic. *Frontiers in Sustainable Food Systems*, *5*. https://www.frontiersin.org/articles/10.3389/fsufs.2021.695347

Gupta, A., & Kaicker, N. (2022). *Dietary Diversity during COVID-19 in India*. *57*(39). https://www.epw.in/journal/2022/39/commentary/dietary-diversity-during-covid-19-india.html

Gupta, A., Malani, A., & Woda, B. (2021). *Explaining the income and consumption effects of covid in india*. National Bureau of Economic Research.

Gupta, S., Seth, P., Abraham, M., & Pingali, P. (2021). COVID-19 and women's nutrition security: Panel data evidence from rural India. *Economia Politica*, 1–28.

Gupta, S., Sunder, N., & Pingali, P. L. (2020). Market Access, Production Diversity, and Diet Diversity: Evidence From India. *Food and Nutrition Bulletin*, *41*(2), 167–185.

Hammer, J., & Spears, D. (2016). Village sanitation and child health: Effects and external validity in a randomized field experiment in rural India. *Journal of Health Economics*, *48*, 135–148.

Kaicker, N., Gupta, A., & Gaiha, R. (2022). Covid-19 pandemic and food security in India: Can authorities alleviate the disproportionate burden on the disadvantaged? *Journal of Policy Modeling*, *44*(5), 963–980. https://doi.org/10.1016/j.jpolmod.2022.08.001

Mahajan, K., & Tomar, S. (2020). Here Today, Gone Tomorrow: COVID-19 and Supply Chain Disruption. *Gone Tomorrow: COVID-19 and Supply Chain Disruption (May 9, 2020)*.

Martorell, R. (2017). Improved nutrition in the first 1000 days and adult human capital and health. *American Journal of Human Biology*, *29*(2), e22952. https://doi.org/10.1002/ajhb.22952

Nguyen, P. H., Kachwaha, S., Pant, A., Tran, L. M., Walia, M., Ghosh, S., Sharma, P. K., Escobar-Alegria, J., Frongillo, E. A., Menon, P., & Avula, R. (2021). COVID-19 Disrupted Provision and Utilization of Health and Nutrition Services in Uttar Pradesh, India: Insights from Service Providers, Household Phone Surveys, and Administrative Data. *The Journal of Nutrition*, *151*(8), 2305–2316. https://doi.org/10.1093/jn/nxab135

Osendarp, S., Akuoku, J. K., Black, R. E., Headey, D., Ruel, M., Scott, N., Shekar, M., Walker, N., Flory, A., Haddad, L., Laborde, D., Stegmuller, A., Thomas, M., & Heidkamp, R. (2021). The COVID-19 crisis will exacerbate maternal and child undernutrition and child mortality in low- and middle-income countries. *Nature Food*, *2*(7), Article 7. https://doi.org/10.1038/s43016-021-00319-4

Ounsted, M., Scott, A., & Ounsted, C. (1986). Transmission through the female line of a mechanism constraining human fetal growth. *Annals of Human Biology*, *13*(2), 143–151.

Rajpal, S., Joe, W., & Subramanian, S. V. (2020). Living on the edge? Sensitivity of child undernutrition prevalence to bodyweight shocks in the context of the 2020 national lockdown strategy in India. *Journal of Global Health Science*, *2*(2).

Royston, P., Altman, D. G., & Sauerbrei, W. (2006). Dichotomizing continuous predictors in multiple regression: A bad idea. *Statistics in Medicine*, *25*(1), 127–141.

Seth, P., Mittra, B., & Pingali, P. L. (2020). *Pandemic Prices: Price Shocks from COVID-19 and Their Implications on Nutrition Security in India*. Tata-Cornell Institute for Agriculture and Nutrition, Cornell University. https://scholar.google.co.in/citations?view_op=view_citation&hl=en&user=gY4WnuwAAAAJ&citation_for_view=gY4WnuwAAAAJ:d1gkVwhDpl0C

Sibhatu, K. T., & Qaim, M. (2018). Review: Meta-analysis of the association between production diversity, diets, and nutrition in smallholder farm households. *Food Policy*, *77*, 1–18. https://doi.org/10.1016/j.foodpol.2018.04.013

UNICEF. (2020). *UNICEF Conceptual Framework on Maternal and Child Nutrition*. https://www.unicef.org/media/113291/file/UNICEF%20Conceptual%20Framework.pdf

UNICEF. (2022). *Severe Wasting: An Overlooked Child Survival Emergency*. https://www.unicef.org/media/120346/file/Wasting%20child%20alert.pdf

Victora, C. G., Onis, M. de, Hallal, P. C., Blössner, M., & Shrimpton, R. (2010). Worldwide Timing of Growth Faltering: Revisiting Implications for Interventions. *Pediatrics*, *125*(3), e473–e480. https://doi.org/10.1542/peds.2009-1519

WHO. (2006). WHO Child Growth Standards based on length/height, weight and age. *Acta Paediatrica (Oslo, Norway: 1992). Supplement*, *450*, 76.

World Bank. (2020). *Global Economic Prospects* [Text/HTML]. World Bank.

https://www.worldbank.org/en/publication/global-economic-prospects