Article

# Predicting Transitions in Stunting, Wasting and Underweight Among Children in Aspirational Districts of India

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### Abstract

This article analysed the trends in reduction of stunting, underweight and wasting among children 6-35 months, as evidenced in the real-time data of the Karnataka Multi-sectoral Nutritional Pilot Project (KMNPP) (2015–2018), implemented in Chincholi Block, Gulbarga District and Devadurga Block, Raichur District, published in The Indian Journal Human Development on 19 May 2022. It attempts to apply the real-time proof of concept re trends and transitions on the baseline data of stunting, wasting and underweight of children 6-35 months extracted from NFHS-5 data of the two lowest quintile households of all the 112 aspirational districts (ADs) using linear, exponential and logarithmic regression, and predicts the improvement of these three measures, after implementation of the KMNPP interventions for a period of five years. The article also projects how this improvement impacts the average aspirational district data regarding these three measures, and the national average taken from NFHS-5. In five years, as per the linear regression trend, stunting decreased from 46.3% to 30.4%, wasting from 24.6% to 9.0% and underweight from 43.0% to 1.2% in the two lowest quintile households of 112 ADs. Due to these changes in two lowest quintile households of aspirational districts, stunting percentage will reduce from 41.7% to 33.6%, wasting from 22.8% to 15.5% and underweight from 38.0% to 20.7% in all the 112 ADs; and nationally, stunting will reduce from 36.2% to 31.4%, wasting from 19.9% to 16.1%, underweight from 31.2% to 23.5%.

Hence, for India to show faster progress in reduction of stunting, wasting and underweight, there is strong justification for replication of the KMNPP interventions in the poorest two quintile households of all 112 ADs.

### Keywords

Aspirational districts, inter-sectoral interventions, child undernutrition, stunting, wasting, transitions in CGF measures, improvement predictions

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# Introduction

Undernutrition and micronutrient deficiency, particularly anaemia, continue to be priority health problems in India, preventing our human capital from achieving its complete cognitive and physical potential. Between NFHS-4 (2015–2016) and NFHS-5 (2019–2020), there has been only 3% improvement in stunting among children, 3.7% improvement in underweight and 1.7% in wasting in a period of four years. Anaemia among children has increased from 58.6% to 67.1%, among women from 53.1% to 57%.

Our HDI ranking, 132 in the Human Development Report, 2021/2022, has remained almost static for the last decade. Amongst the major factors preventing improvement in position is high prevalence of undernutrition and dietary deficit and its several manifestations, namely LBW, underweight, stunted and wasted children, high IMR, MMR, low BMI among adolescents and high anaemia prevalence among women and children.

India has strong national programmes addressing health and nutrition, namely the National Health Mission (NHM), its main components being Health Systems Strengthening, RMNCH+A,<sup>1</sup> Control of Communicable and Non-communicable Diseases and the Integrated Child Development Services (ICDS) with components of Supplementary Nutrition, Pre-school Education, Nutrition/Health Education, Immunisation, Health Check-up, Referral Services.

However, in spite of ICDS operating since 1975, our national data indicates that at least 50% of our population suffers from macro and micronutrient dietary deficit, (NNMB 3rd Repeat Survey, 2012, NNMB Technical Report Number 27, 2017) NFHS-5, 2019–2020 informs that ICDS nutritional coverage is only 50%. Critical programme gaps continue to be grassroots IEC and awareness regarding proper child/adolescent/maternal health and nutritional care, regarding balanced diets within family budgets, regarding safe drinking water, hygiene and sanitation. These critical programme gaps are preventing faster improvement of India's nutritional and health indicators across all age groups.

Public Nutrition is the invisible but foundational layer of Public Health, particularly for Neonatal Mortality Rate, Infant Mortality Rate, Child Mortality Rate, Maternal Mortality Rate, anaemia and immunity levels. NHM interventions have effectively reduced the percentage of mortality rates (Kumar, 2021), which can be reduced by emergency/institutional care, timely treatment and medication. But morbidity and mortality rates related to poor nutritional status, particularly poor inter-generational nutritional status, the manifestations of which are premature birth, LBW, respiratory infections, pneumonia, anaemia, and diarrhoea, will only reduce through effective IEC, behaviour change and multi-sectoral convergence at a household level, addressing the dietary and information deficits and improving the nutritional/health status of the family across the life-cycle.

It is with this objective that the Karnataka Multisectoral Nutrition Pilot Project (KMNPP) was implemented under the leadership of the Karnataka Comprehensive Nutrition Mission (KCNM) (2014–2018). The Mission Strategy, which was intersectoral in nature, was finalised in January 2011, after high-level consultation with experts from Government, nongovernmental and international organisations.<sup>2</sup> This was a community-level initiative which led to significant reductions in three child growth failure (CGF) measures among 6–35-month-old children, thinness levels in adolescent girls, an increase in pregnancy weight gain and a decrease in low birth weight babies.

The human development indicators of Gulbarga and Raichur Districts, which are in North Karnataka, are considerably worse than those in the southern Districts. Among them, Chincholi Block in Gulbarga District ranks 173 and Devadurga Block in Raichur District ranks 176 out of 176 taluks (Human development performance of districts, taluks and urban local bodies in Karnataka: A snapshot. chrome-extension://efaidnbmnnibpcajpcglclefindmkaj/https://publicnutrition.aurosociety.org/wp-content/uploads/2025/04/Snapshot\_English-2\_compressed.pdf) (Box 1).

Nutrition Indicators	India	Karnataka	Raichur	Gulbarga	ADs Average Data from NFHS-5 <sup>d</sup>	Data for Lowest Two Quintile Families Extracted from ADs Average Data <sup>d</sup>
Infant mortality rate	<b>4</b> ]ª	26.9ª	NA	NA	NA	NA
(IMR)	35.2 <sup>⊾</sup>	<b>25.4</b> <sup>ь</sup>				
Maternal mortality rate (MMR)	<b>3</b> °	<b>92</b> °	NA	NA	NA	NA
Stunting % (children	<b>38.4</b> ª	36.2ª	<b>37.2</b> ª	52.2ª	39.4	43.8
below five years of age)	<b>35.5</b> ⁵	35.4 <sup>⊾</sup>	<b>39.8</b> ⁵	<b>34</b> .5⁵		
Wasting % (children	21.0ª	<b>26.1</b> ª	23.2ª	34.0ª	20.7	22.8
below five years of age)	l 9.3⁵	I 9.5 <sup>⊾</sup>	<b>34.9</b> ⁵	25.0 <sup>b</sup>		
Underweight % (children	<b>38.4</b> ª	35.2ª	<b>41.2</b> <sup>a</sup>	56.7ª	35.9	39.3
below five years of age)	32.I <sup>♭</sup>	32.9 <sup>b</sup>	<b>40.7</b> <sup>ь</sup>	36.2 <sup>⊾</sup>		
Infants 6–23 months	<b>9.6</b> ª	<b>8.2</b> ª	<b>3.3</b> ª	<b>2.6</b> ª	11.3	NA
receiving adequate diet %	II.3 <sup>⊾</sup>	I 2.8 <sup>♭</sup>	I 3.0 <sup>ь</sup>	I 5.4 <sup>⊾</sup>		
Anaemia among women	53.lª	<b>44.8</b> ª	58.7ª	<b>43.1</b> ª	61.2	NA
aged 15–49 years %	57.0 <sup>ь</sup>	<b>47.8</b> <sup>♭</sup>	60.4 <sup>ь</sup>	56.0 <sup>⊳</sup>		
Anaemia among children	58.6ª	60.9ª	<b>70.6</b> <sup>a</sup>	<b>72.4</b> ª	69.2	NA
aged 6–59 months %	<b>67.1</b> ⁵	<b>65.5</b> <sup>⊾</sup>	73.6 <sup>ь</sup>	<b>75.I</b> ⁵		
Anaemia among women	<b>59.1</b> ⁵	<b>44.8</b> ª	62.2ª	<b>61.4</b> ª	NA	NA
aged 15–19 years %		<b>47.8</b> <sup>♭</sup>	64.8 <sup>ь</sup>	<b>46.6</b> <sup>⊾</sup>		
Anaemia among pregnant	50.4ª	<b>45.4</b> <sup>a</sup>	<b>73.1</b> ª	53.9ª	NA	NA
women aged 15–49 years %	52.2 <sup>⊾</sup>	<b>45.7</b> ⁵	<b>69.1</b> ⁵	<b>58.0</b> ⁵		
Body mass index (BMI) is	<b>22.9</b> <sup>a</sup>	<b>20.7</b> <sup>a</sup>	20.8ª	22.5ª	23.0	NA
below normal (BMI <18.5	l 8.7⁵	I 7.2 <sup>⊾</sup>	23.3 <sup>⊾</sup>	20.8 <sup>b</sup>		
kg/m²) among women						
aged 15–49 years %						
Female literacy rate	<b>68.4</b> ª	71.7ª	54.3 <sup>⊾</sup>	68.2 <sup>⊾</sup>	62.0	NA
(15–49 years)%	71.5⁵	76.7 <sup>⊾</sup>				

Box I. Nutrition Indicators of India, Karnataka, Raichur and Gulbarga Districts and Aspirational Districts (ADs).

Notes: aNFHS-4 (2015-2016). bNFHS-5 (2019-2020). SRS bulletin (2016-2018). dAuthors.

Unique features of KMNPP's intergenerational, inter-sectoral strategy that address the root causes of India's malnutrition are:

- Directly addressing the inter-generational cycle of malnutrition by simultaneously targeting and addressing the nutritional needs of infants, children, adolescent girls and pregnant and nursing mothers.
- 2. Bridging the information deficit through a sustained, multi-layered general public awareness campaign, most importantly through interpersonal communication, to reach the general public, focusing at the household level, regarding proper nutritional practices within existing family budgets and proper child, adolescent and maternal care and creating demand for on-going government programmes. Bridging the calorie-protein micronutrient deficit among the inter-generational target groups by providing appropriate fortified multigrain nutritious food supplementation for consumption.
- 3. Accelerating, integrating and tightly monitoring multi-sectoral ongoing programmes that have an impact on malnutrition, such as Immunisation and Vitamin A Supplementation, Anaemia Control,

Water and Sanitation and achieving convergence between the ongoing programmes so that they operate simultaneously at family level, and filling programmatic gaps. Increasing programme coverage by demand creation through involvement of the community, NGOs, SHGs and VPs.

- 4. Making available low-cost energy foods for the general population.
- 5. Real-time monitoring of the beneficiaries' nutrition indicators, particularly underweight, stunting and wasting of children, body mass index of adolescent girls, pregnancy weight gain and incidence of low-birth-weight babies

The Box 2 gives the number of beneficiaries of the project.

Block	Children 0–5 Months	Children 6–35 Months	Adolescent Girls 11–18 Years	Pregnant Women	Lactating Mothers	Total
Chincholi	417	6,038	8,107	783	1,660	17,005
Devadurga	152	6,522	8,396	841	2,090	18,001
Total	569	12,560	16,503	1,624	3,750	35,006

Box 2. Beneficiaries registered at the start of the project.

Details regarding methodology, interventions and outcomes are available in three published papers emerging from the real-time project data.

- 1. Multisectoral nutrition interventions and their impact on the nutritional status of children: An open experiment in two remote blocks of Karnataka, India (Rao et al., 2022).
- 2. Multisectoral nutrition interventions and their impact on BMI and thinness levels among adolescent girls: An open experiment in two remote blocks of Karnataka, India (Rao et al., 2022).
- 3. Multisectoral nutrition interventions and their impact on pregnancy weight gain and low birth weight: An open experiment in two remote blocks of Karnataka, India (Rao et al., 2023).

As a result of the intergenerational, inter-sectoral interventions implemented through KMNPP, the average cost of which was ₹3.70 crores per year per Block, there was a significant improvement in the three child growth failure (CGF) measures, during 11 months of preparatory phase which was also accompanied by an intense multi-layered IEC campaign (December 2015 to October 2016) and two years of regular implementation of interventions (Baseline: September 2016 and Endline: September 2018), among both the cross-section group of 8,606 children aged 6–35 months and among the cohort group of 699 children (Box 3).

- 1. The percentage of 'normal' children, that is, those who did not suffer from undernutrition, stunting and wasting increased from 21.7% at baseline to 30.5% at the end line in the cohort group and from 20.5% at baseline to 29.5% at end line in the cross-sectional group.
- 2. Underweight decreased from 44.3% at baseline to 21.3% at end line in the cohort group and from 44.6% at baseline to 22.6% at end line in the cross-sectional group.
- 3. Wasting decreased from 15.6% at baseline to 5.4% at the end line in the cohort group and from 14.4% at baseline to 6.1% at the end line in the cross-sectional group.
- 4. Stunting decreased from 70.0% at baseline to 63.2% at end line and severe stunting dropped from 46.7% to 41.0% in the cross-section group. In the cohort group, there was an insignificant reduction in

<b>Box 3.</b> Interventions, Number of Benefit Nutrition Calculated Only for Children.	ciaries and Operational Cost per Block (Ave	srage) per Year (Devadurga Block, Raicl	nur District)—Supplementary
Unique Features	Number of Beneficiaries from the Two Poorest Quintile Households	Interventions	Average Cost per Year
Directly addressing the inter- generational cycle of malnutrition by simultaneously targeting and addressing the nutritional needs of infants, children, adolescent girls and pregnant and nursing mothers	Children 0–5 months: 569 Children 6–35 months: 12,560 Adolescent girls 11–18 years: 16,503 Pregnant women: 1,624 Lactating mothers: 3,750	IEC and nutrition/health interventions were directed towards the three links of the inter-generational cycle, namely children, adolescent girls and pregnan and lactating women Training	Training—₹500,000 per year salaries, overheads, travel, operating costs for field partners and state-level tmonitoring agency ₹1,00,000
Bridging the information deficit through a sustained, multi-layered general public awareness campaign	All 184 villages of the Block	Multilayered IEC Campaign with emphasis on inter-personal counselling	IEC campaign ₹25,000,00
Bridging the calorie-protein micronutrient deficit among the inter- generational target groups by providing appropriate fortified multigrain nutritious food supplementation for consumption	All 6,522 children aged 6–35 months in all villages in Devadurga Block	Cost only for children 6–35 months @₹5 per child	₹1,18,62,500
Convergence—Accelerating, integrating and tightly monitoring multi-sectoral ongoing programmes	Through the Nutrition and Health Cards to all beneficiaries Village Nutrition Volunteers (VNVs) appointed in each village.	Average number of villages in Aspirational block Devadurga−184 @₹5,000 per VNV per month	Honorarium to VNVs ₹I,I0,40,000
Making available low-cost energy foods for the general population	The activity was done after the World Bank project but was disturbed by COVID lockdowns	Marketing activities were undertaken after the closure of the project	Zil
Real-time monitoring of the beneficiaries' nutrition indicators	All 6,522 Children aged 6–35 months in all villages in Devadurga Block	Through VNVs, they recorded monthly real-time anthropometric and health data of all children. Supervised and reviewed by field partner and KCNM	₹20,00,000
		Dasenine and Concurrent for Monitoring Total	₹3,70,02, 500 (rounded off to ₹3,70,00,000

severe stunting from 45.2% to 43.8% and an insignificant increase in moderate stunting from 18.7% to 21%. This is because 'while 15.4% of the total cohort group progressed from stunting to non-stunting, a new group of 19% cohort children transitioned from wasting and underweight to stunting and 2.7% children transitioned from stunting to wasting and underweight' (Rao et al., 2022a).

The following transitions and trends were mapped through the real-time data from baseline (September 2016) when the children's mean age was 9.6 months till the end of the project (September 2018) when their mean age was 33.6 months:

- 1. 25% of stunted, 28% wasted and 24% of underweight children at baseline transitioned to normal (no stunting, no wasting and no underweight) at the end of the project, due to optimal gain in both weight (200–254 grams per month) and height (0.54–0.7 centimetres per month) for age in the cohort group.
- 2. 27% of underweight and 29% of wasted children of the total cohort group at 9.6 months were no longer underweight or wasted and transitioned into moderate stunting at the end of the project.
- 3. 18.2% of underweight and 6.6% wasted children at baseline of the cohort group were no longer underweight or wasted by the end of the project and transitioned to moderate and severe stunting. Hence, while 15.4% of the total cohort group progressed from stunting to non-stunting, a new group of 19% cohort children transitioned from wasting and underweight to stunting and 2.7% children transitioned from stunting to wasting and underweight.
- 4. From the stunted category, taller children with higher linear growth and lower weight gain became severely wasted; shorter children with poor weight gain developed severe underweight.
- 5. From the wasted category, taller wasted children at baseline with lower weight gain remained wasted, baseline taller children with optimal weight gain became normal, and those children who gained constant weight and poor height gain transitioned into the stunted category.
- 6. From the underweight category, children whose weight gain for age was optimal but height gain for age was not optimal, transitioned from underweight to severe stunting by 33.6 months;
- 7. Children with rapid weight gain but slow height gain transitioned to the moderately stunted category; children with rapid weight and height gain till 27 months but later due to drop in weight gain transitioned to severe wasting, and children with poor/stagnated weight gain continued with severe underweight.

This constant transition between the three CGF measures provided clear evidence that they impact each other constantly and coexist simultaneously in different combinations, as children grow. Data analysis also provided evidence that higher baseline height and faster linear growth were prominent determinants for wasting among children and acute thinness among adolescent girls in the two lowest quintile households (Rao et al., 2022).

These are completely new findings and trends which we hope to research further.

# Aspirational Districts (ADs) Programme

The government of India 2018 initiated the Aspirational Districts Programme with the aim of transforming the 112 most under-developed districts of the country, quickly and effectively, with broad contours of the programme being convergence of State and Central programmes, collaboration of Central, State and District administrators and competition among the districts through monthly delta ranking, all driven by

a mass movement. The ranking is based on the incremental progress made across 49 key performance indicators (KPIs) under five broad socio-economic themes—Health & Nutrition, Education, Agriculture & Water Resources, Financial Inclusion & Skill Development and Infrastructure (NITI Aayog, 2023).

The objective of this article is to calculate the average percentage of stunting, wasting and underweight among children aged 6–35 months from the two lowest percentile households in the ADs, predict improvement in the three indicators based on the results of KMNPP over a period of five years, and calculate the impact that this improvement will have in reducing the incidence of stunting, wasting and underweight in the ADs and on the national average.

We started our exercise by extracting the human development indicators of the Aspirational Districts from NFHS-5 and found that the indicators of 70% of the most backward ADs were similar to those of Chincholli Block, Gulbarga District and Devadurga Block, Raichur District, where the KMNPP was implemented (Box 1).

We then extracted data pertaining to the lowest two quintile families of the ADs pertaining to stunting, wasting and underweight, so that they were comparable with the baseline data pertaining to 40% poorest households of the KMNPP study.

Based on the trends recorded through real-time data in the KMNPP, the aim of this article is to make annual predictions of the three CGF measures, namely stunting, wasting and underweight, in the lowest two quintile households of the 112 aspirational districts of India for a period of five years. These trends intrinsically include and factor in the pattern and duration of the transition of these three CGF measures during five years of implementation of KMNPP interventions.

NFHS-5 (2019–2021) data pertaining to the lowest two quintile households regarding stunting, wasting and underweight levels of 6–35-month-old children in 112 aspirational districts of India has been extracted, and these figures will be treated as baseline data/pre-intervention levels. These data are comparable with corresponding data contained in the baseline of Chincholli and Devadurga Blocks of KMNPP. Projections regarding improvement of the three indicators will be calculated based on the results of the KMNPP interventions if they are replicated in these 112 aspirational districts with the same coverage and rigor for five years.

Specific objectives include:

- 1. Using percent stunting, wasting and underweight levels according to duration of intervention in months—fit three alternate regression curves (linear, exponential and logarithmic) for stunting, wasting and underweight measures in KMNPP findings.
- Using NFHS-5 (2019–2021) raw data pertaining to the lowest two quintile households, estimate percent stunting, wasting and underweight levels among 6–35-month-old children in 112 aspirational districts.
- 3. Predict annual estimates of percent stunting/wasting/underweight levels in two lowest quintile households of 112 aspirational districts of India, during the next five years from NFHS-5 (2019–2021), under three alternate scenarios of linear, exponential and logarithmic trends—assuming KMNPP interventions are replicated here, with the same rigor and coverage for five years.
- 4. From the pre-intervention (NFHS-5) levels of stunting, wasting, underweight and normal children among 6–35 months old children in two lowest wealth quintile households of 112 aspirational districts, predict these levels five years after interventions, if KMNPP interventions follow linear regression trend. Also estimate the impact of these predictions on the levels of stunting, wasting and underweight, after five years, on the data pertaining to all 112 aspirational districts of India and on the national average.

# **Data and Methods**

### Need for This Research

According to recent Joint Malnutrition Estimates 2023 (World Health Organization, 2023), there is insufficient progress in reaching the 2025 World Health Assembly goals<sup>3</sup> and the 2030 Sustainable Development Goal (SDG) target 2.2.<sup>4</sup> On this issue, India recorded mixed progress with 16 million fewer stunted children in 2022 as compared to 2012,<sup>5</sup> while wasting remains a concern with a prevalence of 19% (UNICEF and WHO, 2023). With the launch of Poshan Abhiyaan, in 2018, and Poshan 2.0 in 2023, we expect intensified political commitment, and more innovative efforts of development partners, for improving nutritional outcomes in India. To track progress in nutrition outcomes, there is a need for projecting stunting, wasting and underweight measures in the context of different interventions like bridging the information deficit at family level regarding proper child, maternal and adolescent nutritional and health care, complete immunisation, storage of drinking water, hygienic sanitation, diarrhoea prevention; bridging the dietary deficit that afflicts at least 50% of our population; bridging programme gaps, particularly in high burden districts or the aspirational districts and in the two lowest quintile households of India.

To the best of our knowledge, there is no study that has predicted improvement in nutrition measures among 6–35-month-old children using three alternative prediction scenarios based on validated pilots and proof of concept. We are also not aware of any study that has predicted improvement in nutrition measures among 6–35 months old children, taking into account the assessment and prediction of transitions that would occur among the three CGF measures among the lowest two quintiles of the 112 aspirational districts of India, assuming these districts receive KMNPP interventions with the same rigor and coverage similar to that of KMNPP, for five years.

### Data

For this article, we used data from multiple sources. Percent changes/transitions among a cross-section of children aged 6–35 months with stunting, wasting and underweight were obtained at seven-time points during three broad intervention periods [seven-time points starting from zero month are: Baseline-September 2016 (zero month); only IEC intervention period—October–December 2016 (3rd month); IEC + supplementary nutrition intervention period, January 2017 to September 2018; June 2017 (9th month), December 2017 (15th month), March 2018 (18th month), June 2018 (21st month) and September 2018 (24th month)] from KMNPP (Rao et al., 2022). The list of 112 ADs was obtained from the Niti Aayog website (https://www.niti.gov.in/sites/default/files/2022-09/List-of-Aspirational-Districts.pdf).

Data regarding wasting, stunting and underweight of children aged 6–35 months old for the 112 aspirational districts was extracted from NFHS-5 raw data regarding height, weight and age of children with below –2 standard deviations (moderate/severe) as the cut-off criteria for calculation of percent stunting, percent wasting and percent underweight levels.

KMNPP study transition results of the cross-sectional group were used to estimate how transitions and improvements within the three CGF measures occur during the intervention phase in the two poorest quintile households of 112 Aspirational Districts and to estimate the percentage of children who became healthy/normal during the intervention phase.

Why did we use cross-sectional group results of KMNPP to predict CGF measures for aspirational districts?

The KMNPP study provides results of three CGF measures and transition among these three CGF measures according to seven durations of intervention (in months), from September-2016 (pre-intervention) to September-2018 (endline). For predicting future CGF measures and for understanding transition among the CGF measures among the two poorest quintile households in aspirational districts after interventions, we have only used cross-sectional results of KMNPP as the basis, as children included in the cross-sectional group of KMNPP, have come within the project at any time and have left the project anytime during the intervention phase, in a natural way, that is usually the case in any public health intervention conducted in a large geography like a Block or District.

While predicting changes and transitions in the CGF measures, it is assumed that a similar inward and outward mobility of the same percentage of people, including children below three years, would take place, in a natural manner. Hence, the changes in three CGF measures and transitions among these three measures have been estimated from the cross-sectional group of 6–35-month-old children in KMNPP, as this would provide a more reliable yardstick in the study geography as compared to measuring changes in the cohort group of children, which is an artificially created group from within the cross-sectional group, and cannot be compared to the baseline which is extracted from the NFHS-5 data, which is also of cross-sectional nature, and not cohort data.

## Methods

To understand the trends in decline of percent stunting/wasting/underweight among 6–35-month-old children in KMNPP according to duration of intervention in months, we have fitted regression curves between stunting/wasting/underweight values according to seven-time points of duration of intervention, using ordinary least squares (OLS) method. The OLS builds a line of best fit that would serve as the most accurate way of depicting the spread of the data points with a single line and offers a greater degree of objectivity, in the absence of outliers (Barnes & Forde, 2021). In the regression model, duration of intervention in months served as predictor variable ( $x_i$ ) while the respective stunting/wasting/underweight values served as response variable ( $y_i$ ). As there is no definitive, quantitative relationship between decline in three CGF measures among 6–35-month-old children and an increase in duration of intervention period in months in the KMNPP and, we are also not sure whether the reduction in these three measures follows a linear or non-linear regression trend with increase in duration of interventions, and hence, we have fitted three types of regression curves, namely linear, exponential and logarithmic. Results of these three regression curves are used for predicting stunting/wasting/underweight values at annual durations of interventions, for five years.

Using seven durations of interventions in KMNPP as xi and their respective stunting/wasting/ underweight values as yi—we have fitted the following three regression lines:

- 1. Linear regression line  $\hat{y} = b_0 + b_1 x_i$ , and estimated 'b<sub>1</sub>' the slope and 'b<sub>0</sub>' the y-intercept (i.e., the value of y when x = 0). For this regression line, 95% confidence interval is measured using the formula  $y_i = b_i \pm t_{a/2} \sum_{n=2}^{n} \operatorname{se}(b_i)$ .
- 2. Exponential regression line  $\hat{y} = b_{0*}e^{b1xi}$ , and estimated 'b<sub>1</sub>' the slope and 'b<sub>0</sub>' the y-intercept (i.e., the value of y when x = 0). For this regression line, 95% confidence interval is measured using the formula  $y_{i=}b_i \pm e^{t\alpha/2, n-2*se(bi)}$
- 3. Logarithmic regression line  $\hat{y} = b_0 + b_{1*} \ln(x_i)$ , and estimated ' $b_1$ ' the slope and ' $b_0$ ' the y-intercept (i.e., the value of y when x = 0). For this regression line, 95% confidence interval is measured using the formula  $y_i = b_i \pm t_{a/2, n-2} * \ln[se(b_i)]$ .

The main objective of this article is to predict decline in stunting/wasting/underweight levels among 6–35-month-old children, with implementation of inter-sectoral inventions, as in KMNPP, for the lowest two quintiles, for a duration of five years in 112 aspirational districts, with the same rigour of KMNPP.

For predicting decline in stunting/wasting/underweight levels in the lowest two quintile households of 112 aspirational districts according to annual intervals and according to three types of regression trends, we have used data pertaining to the two lowest quintiles which we extracted from the raw data of the ADs from NFHS-5. This constitutes the 'intercept value' for predicting stunting/wasting/underweight levels in 112 aspirational districts when KMNPP interventions are implemented in these districts. We used 'b,' values of each regression line from KMNPP as the 'slope value'.

KMNPP data analysis provided unique evidence for the first time, on how three CGF measures interact with each other leading to transition among themselves, as the age of the child increases and as the duration of interventions progresses. These transitions are integral to predicting the reduction of stunting, wasting and underweight as contained in this article.

# Results

Using seven data points, Table 1 provides three regression equations (linear, exponential and logarithmic) for each of the three CGF measures of stunting, wasting and underweight among a cross-section of 6–35-month-old children in KMNPP from September 2016 to September 2018. For each of the three fitted regression equations, Table 1 also provides  $R^2$  value (or goodness of fit) of each equation. An  $R^2$  value range between 0.00 and 1.00 indicates how well the regression model explains the observed data of KMNPP at seven-time points for the three CGF measures. For example, an  $R^2$  value of 0.74 implies 74% of the variability observed in the target variable (stunting/wasting/underweight) and the same is explained by the regression model/equation. A higher  $R^2$  value indicates greater variability in the model and a better fit. For three CGF measures and for three alternate regression scenarios  $R^2$  values ranged between 71% and 83%, implying goodness of fit of three regression equations, which are robust at 71–83 percentage points.

The 'slopes' of regression equations for stunting/wasting/underweight in KMNPP (Table 1) are used to predict annual stunting/wasting/underweight levels of 6–35-month-old children from the lowest two quintile households of 112 aspirational districts during the next five years. The value of 'intercept' for annual prediction of stunting/wasting/underweight among 6–35-month-old children is taken from the two lowest quintile households of 112 aspirational districts from NFHS-5 (2019–2021).

Table 2 provides the three CGF measures among 6–35-month-old children, extracted from NFHS-5, according to caste, wealth quintiles in 112 aspirational, 595 non-aspirational and all the 707 districts of

	Linear Regression	Exponential Regression	Logarithmic Regression
Stunting	$y = -0.2642 \times + 68.811$	$y = 68.819e^{-0.004\times}$	$y = -2.019 \ln(x) + 69.946$
	$R^2 = 0.7381$	$R^2 = 0.7381$	$R^2 = 0.7095$
Wasting	$y = -0.2599 \times + 13.198$ $R^2 = 0.8348$	$y = 13.486e^{-0.027x}$ $R^2 = 0.8226$	$y = -1.998 \ln(x) + 14.342$ $R^2 = 0.812$
Underweight	$y = -0.6966 \times + 41.27$	$y = 41.741e^{-0.022\times}$	y = -5.302ln(×) + 44.218
	$R^2 = 0.7846$	R <sup>2</sup> = 0.7717	R <sup>2</sup> = 0.7483

 Table 1. Three Types of Regression Scenarios for the Three CGF Measures in Children Aged 6–35 Months with

 the Progress of KMNPP Interventions During September 2016 to September 2018.

	112 A	spirational Dist	ricts	595 Nor	1-aspirational D	listricts	All 70	17 Districts of	India
			% Under-			% Under-			% Under-
	% Stunting	% Wasting	weight	% Stunting	% Wasting	weight	% Stunting	% Wasting	weight
Caste									
Scheduled Caste/tribe (SC/ST)	45.9	24.7	43.3	39.I	21.1	34.3	40.4	21.7	36.0
Other backward caste (OBC)	40.0	22.1	35.8	34.8	19.0	29.2	35.7	19.5	30.3
Others	35.6	19.9	30.3	29.5	17.5	24.4	30.2	17.8	25.1
Wealth quintile									
Poorest/poor (lowest/second)	46.3	24.6	43.0	43.0	22.2	38.2	43.8	22.8	39.3
Middle	37.2	19.5	30.6	34.8	18.6	28.7	35.1	18.7	29.0
Richer (fourth)	29.2	19.5	25.5	29.0	17.2	23.9	29.0	17.4	24.1
Richest (highest)	21.6	17.5	18.7	23.7	16.1	18.5	23.5	16.1	18.5
Total	41.7	22.8	38.0	35.2	19.4	29.9	36.2	19.9	31.2

Table 2. Caste, Wealth Index-wise Percent STUNTED, WASTED and UNDERWEIGHT Levels Among 6–35-month-old Children, in Aspirational, Nonaspirational and all the Districts of India, in 2019–2021.

Source: NFHS-5 data analysis by authors.

India. In 112 aspirational districts of India, among 6–35-month-old children, percent stunting was 41.7, wasting was 22.8 and underweight was 38.0. The three total CGF measures of stunting, wasting and underweight in 112 aspirational districts, respectively, are 6.5, 3.4 and 8.1 percentage points higher than the non-aspirational districts of India. Irrespective of aspirational and non-aspirational districts, all three CGF measures are highest among the two lowest quintile households, scheduled caste/scheduled tribe households, slightly less in other backward castes and lowest among the remaining households of India. Similarly, irrespective of aspirational districts, with an increase in wealth quintile there is a decrease in all the three CGF measures.

Using NFHS-5 (2019–2021) value of 46.3 as pre-intervention/baseline percent stunting level among lowest two quintile households of 6–35-month-old children in 112 aspirational districts and assuming decline in percent stunted children in these households will follow linear/exponential/logarithmic trend of KMNPP during the next five years, and assuming KMNPP interventions are replicated in these households with the same coverage and rigor of KMNPP for next five years—Table 3 provides annual changes in percent stunted children as well as percent decline in proportion of stunted children as compared to pre-intervention level. Figure 1 provides annual decline in percent stunted children from the baseline, using three types of regression scenarios.

Figure 1 and Table 3 clearly indicate that after five years of interventions, stunting levels will reduce sharply (33%) if decline in stunting follows a linear regression trend as compared to logarithmic (16%) or exponential (20%) regression trends. In five years, the pre-intervention stunting level of 46.3% will come down to 30.4% (95% CI: 25.1%–35.8%), if decline in stunting follows a linear regression trend. With a relatively slower pace of decline, in five years, stunting will be 36.4% (95% CI: 31.1%–41.8%) if stunting follows an exponential trend and will be 38.0% (95% CI: 32.7%–43.4%) if decline in stunting follows logarithmic regression trend.

Figure 2 and Table 4 provide percent change in proportion of wasted children from pre-intervention level (2019–2021) of 24.6% in the poorest two quintile households of 112 aspirational districts of India

	Linear Regr	ession Trend	Exponential R	egression Trend	Logarithmic Re	egression Trend
Timing of Intervention Period	% Stunted Children (95% CI)	% Decline in Stunted Children from Prior-to- intervention	% Stunted Children (95% CI)	% Decline in Stunted Children from Prior-to- intervention	% Stunted Children (95% CI)	% Decline in Stunted Children from Prior-to- intervention
Baseline (2019–2021)	46.3	_	46.3	_	46.3	-
12 months	43.1 (37.8–48.5)	-4.8	44.1 (38.8–49.5)	-2.6	41.3 (35.9–46.6)	-8.9
24 months	40.0 (34.6–45.3)	-11.8	42.1 (36.7–47.4)	-7.1	39.9 (34.5–45.2)	-12.0
36 months	36.8 (31.5–42.1)	-18.8	40.1 (34.8–45.4)	-11.5	` 39.1 (33.7–44.4)	-13.8
48 months	33.6 (28.3–39.0)	-25.8	38.2 (32.9–43.5)	-15.6	38.5 (33.1–43.8)	-15.0
60 months	30.4 (25.1–35.8)	-32.8	36.4 (31.1–41.8)	-19.6	38.0 (32.7–43.4)	-16.0

Table 3.	Percent STU	NTED Ch	nildren Ageo	d 6–35 Mo	onths Durir	ng Baseline	in Two	Lowest \	Nealth (	Quintiles	of
112 Aspir	ational Distric	ts of India	and During	Five Years	of Interve	ntion, and <i>i</i>	Annual F	Percent De	ecline in	Proportio	on
STUNTED	D Children—I	f Decline i	n Stunting i	n This Gro	oup Follows	s Three Ty	pes of R	egression	Trends	of KMNF	Ρ.



Figure 1. Percent Stunted Children During Baseline and Five Years of Intervention, Using Three Types of Regression Scenarios.



Figure 2. Percent Wasted Children During Baseline and Five Years of Intervention, Using Three Types of Regression Scenarios.

if decline in percent wasted children in these households follows linear/exponential/logarithmic trends during next five years and assuming KMNPP interventions are replicated in all these households with the same coverage and rigor of KMNPP. Decline in wasting levels will be maximum (80.2%) according to the exponential regression trend as compared to linear (63.4%) or logarithmic (33.3%) regression trends.

	Linear Regr	ession Trend	Exponential R	egression Trend	Logarithmic Regression Trend		
Timing of Intervention Period	% Wasted Children (95% Cl)	% Decline in Wasted Children from Prior-to- intervention	% Wasted Children (95% Cl)	% Decline in Wasted Children from Prior-to- intervention	% Wasted Children (95% Cl)	% Decline in Wasted Children from Prior-to- intervention	
Baseline (2019–2021)	24.6	-	24.6	_	24.6	-	
12 months	21.9 (17.0–26.8)	-11.0	17.8 (12.9–22.7)	-27.7	19.6 (14.7–24.6)	-14.6	
24 months	18.4 (13.4–23.3)	-25.4	12.9 (7.9–17.8)	-47.7	18.3 (13.3–23.2)	-25.8	
36 months	15.2 (10.3–20.2)	-38.0	9.3 (4.4–14.2)	-62.2	17.4 (12.5–22.4)	-29.1	
48 months	2.  (7.2–17.1)	-50.7	6.7 (1.8–11.7)	-72.6	16.9 (11.9–21.8)	-31.4	
60 months	9.0 (4.1–13.9)	-63.4	4.9 (0.0–9.8)	-80.2	16.4 (11.5–21.4)	-33.3	

 Table 4.
 Percent WASTED Children Aged 6–35 Months During Baseline in Two Lowest Wealth Quintiles of 112

 Aspirational Districts of India and During Five Years of Intervention, and Annual Percent Decline in Proportion

 Wasted Children—If Decline in Wasting in This Group Follows Three Types of Regression Trends of KMNPP.

From the pre-intervention wasting level of 24.6%, in five years, wasting level will drop to 4.9% (95% CI: 0.0%–9.8%) if decline in wasting levels follow an exponential regression trend, to 9.0% (95% CI: 4.1%–13.9%) if wasting follows linear trend and to 16.4% (95% CI: 11.5%–21.4%) if decline in stunting follows logarithmic regression trend. The exponential trend indicates that the decline in wasting was sharper during the initial year, and the pace of decline slowed with an increase in duration of interventions.

Figure 3 and Table 5 provide percent change in proportion of underweight children from preintervention level of 43.0% in the poorest two quintile households of 112 aspirational districts of India if decline in percent underweight in these households follows linear/exponential/logarithmic trend during the next five years and assuming KMNPP interventions are replicated in these households with the same coverage and rigor of KMNPP. If KMNPP interventions continue in these households for five years, underweight level will become negligible (1.2%) if decline in underweight follows a linear regression trend; it will be 11.5% (95% CI: 0.0%–25.1%) if decline in underweight follows exponential trend; and will be 21.3% (95% CI: 7.6%–34.9%) if decline in underweight follows logarithmic regression trend.

Table 6 provides percent of stunted, wasted, underweight and normal children (non-stunted, non-wasted, non-underweight) among 6–35-month-old children at pre-intervention level (NFHS-5) and five years after implementation of KMNPP interventions in two lowest wealth quintile households of 112 aspirational districts, if decline in these measures follows linear regression trend. Table 6 also provides the impact of five years of KMNPP interventions in two lowest wealth quintile households on the changes in stunting, wasting and underweight levels in all the 112 aspirational districts and in all the 707 districts in India constituting the national average. This will be in addition to the improvement which will happen on account of ongoing programmes and general improvement in the standard of living.

As a result of KMNPP interventions for five years in two lowest wealth quintile households of 112 aspirational districts, the pre-intervention (2019–2021) stunting level of 46.3% will decline to 30.4% (95% CI: 25.1%–35.8%) in five years, the pre-intervention wasting level of 24.6% will reduce to 9.0%



Figure 3. Percent Underweight Children During Baseline and Five Years of Intervention, Using Three Types of Regression Scenarios.

**Table 5.** Percent UNDERWEIGHT Children Aged 6–35 Months During Baseline in Two Lowest Wealth Quintiles of 112 Aspirational Districts of India and During Five Years of Intervention, and Annual Percent Decline in Proportion Underweight Children—If Decline in Underweight in This Group Follows Three Types of Regression Trends of KMNPP.

	Linear R Tr	egression end	Exponentia Tr	l Regression end	Logarithmic Regression Trend	
Timing of Intervention Period	% Underweight Children (95% CI)	% Decline in Underweight Children from Prior-to- intervention	% Underweight Children (95% CI)	% Decline in Underweight Children from Prior-to- intervention	% Underweight Children (95% CI)	% Decline in Underweight Children from Prior-to- intervention
Baseline (2019–2021)	43.0	_	43.0	_	43.0	_
12 months	34.6 (21.0–48.3)	-19.4	33.0 (19.4–46.7)	-23.2	29.8 (16.2–43.5)	-30.6
24 months	26.3 (12.6–39.9)	-38.9	25.4 (11.7–39.0)	-41.0	26.1 (12.5–39.8)	-39.2
36 months	17.9 (4.3–31.6)	-58.3	19.5 (5.8–33.1)	-54.7	24.0 (10.3–37.7)	-44.2
48 months	9.6 (0.0–23.2)	-77.8	15.0 (1.3–26.8)	-65.2	22.5 (8.8–36.1)	-47.7
60 months	l.2 (0.0–14.9)	-97.2	11.5 (0.0–25.1)	-73.3	21.3 7.6–34.9)	-50.5

 Table 6. Projected Levels of Three CGF Measures in 6–35-month-old Children in the Two Lowest Wealth

 Quintiles Households of 112 Aspirational Districts Five Years After Implementation of KMNPP Interventions, If

 Decline in the Measures Follows Linear Regression Trend.

	In the Two L Quintile Hou Aspiration	owest Wealth seholds of 112 al Districts	In All 112 A Distr	spirational icts	In All 707 of In	Districts dia
	Pre- intervention (As per NFHS-5)	After Five Years of Intervention (95% CI)	Pre- intervention (As per NFHS- 5)	After Five Yearsª	Pre- intervention (As per NFHS- 5)	After Five Years⁵
Stunting	46.3	30.4 (25.1–35.8)	41.7	33.6	36.2	31.4
Wasting	24.6	9.0 (4.1–13.9)	22.8	15.5	19.9	16.1
Underweight	43.0	1.2 (0.0–14.9)	38.0	20.7	31.2	23.5
Not wasted, not stunted, not underweight	37.5	54.8 (52.3–57.3)				

**Notes:** Impact of interventions in two lowest wealth quintile households of 112 aspirational districts on all the 112 aspirational districts and on all the 707 districts of India, after five years.

<sup>a</sup>Decline after five years according to KMNPP trend from NFHS-5 indicators, among the poorest two quintile households of 112 aspirational districts (40%). In the remaining 60% population, the decline in CGF measure will continue to follow the trend that was noticed during the five-year period of NFHS-4 and 5. Predicted figure, five years after interventions, will be in addition to the improvements which will happen on account of ongoing programmes and improvement in the standard of living in all the 112 aspirational districts of India.

<sup>b</sup>Decline after five years according to KMNPP trend from NFHS-5 indicators, among the 15% child population below three years of all the 707 districts of India, which constitutes children from the poorest two quintile households of the Aspirational districts. Among the remaining 85% children, the decline in CGF measures will continue to follow the trend that was noticed during the five-year period of NFHS-4 and 5. Predicted figure, five years after interventions will be in addition to the improvements which will happen on account of ongoing programmes and improvement in the standard of living in all the 707 districts of India.

(95% CI: 4.1%–13.9%) in five years, and pre-intervention underweight level of 43.0% will decline to 1.2% (95% CI: 0.0%–14.9%) in five years. During five years of intervention in this population, proportion of normal children (not stunted, not wasted, not underweight) will increase from 37.5% to 54.8% (95% CI: 52.3%–57.3%). Due to impact of KMNPP interventions in two lowest wealth quintile households of 112 aspirational districts, there will be a decline in stunting from a pre-intervention level of 41.7% to 33.6% in five years; wasting will decline from a pre-intervention level of 22.8% to 15.5%, and underweight will decline from a pre-intervention level of 38% to 20.7% in five years. In the national average constituting 707 districts of India, stunting will decline from a pre-intervention level of 19.9% to 16.1%, and underweight will decline from a pre-intervention level of 31.2% to 23.5% in five years.

# Discussion

For meeting WHA/SDG targets of malnutrition in India, it is necessary to reduce stunting, wasting and underweight levels of children, particularly in poor households of the most backward regions of the

country, namely aspirational districts. Although the Government of India, state governments, international organisations and NGOs are working on multiple nutrition-specific and nutrition-sensitive interventions, there is limited literature on the impact of a multi-sectoral and inter-generational nutrition intervention on changes in three CGF measures and no literature on transitions within these three measures in India and particularly in aspirational districts of India—if such interventions are replicated for a long period of time of five years. Through this study, we have tried to estimate the CGF measures among 6–35-monthold children in the two lowest quintiles of 112 aspirational districts of India, and their improvement if KMNPP interventions are replicated in all these aspirational districts for five years with the same rigor and coverage of KMNPP. We have also predicted three CGF measures in aspirational districts under three alternative scenarios. Our salient findings are as follows:

- 1. Using seven data points for three CGF measures among 6–35-month-old children of KMNPP, the  $R^2$  value explained by the fitted regression curves under three alternative scenarios range between 71% and 83%, implying 71%–83% of the variance in the three CGF measures which can be explained by the predictor variable (i.e., duration of intervention in months).
- 2. In 112 aspirational districts of India among 6–35-month-old children in 2019–2021, percent stunting was 41.7, wasting was 22.8 and underweight was 38.0. The three CGF measures of stunting, wasting and underweight in 112 aspirational districts, respectively, are 6.5, 3.4 and 8.1 percentage points higher than the non-aspirational districts of India. However, in the poorest two quintile households of aspirational districts stunting, wasting and underweight were 46.3%, 24.6% and 43%, respectively (Table 2).
- 3. Using NFHS-5 data, CGF measure as per intervention/intercept value, using three alternative scenarios of regression trend and assuming KMNPP interventions are replicated in the poorest two quintile households in 112 aspirational districts for five years with the same rigor and coverage as KMNPP: The pre-intervention stunting (46.3%) will decline to 30.4%–38.0% in five years, under three alternative scenarios; the pre-intervention wasting (24.6%) will decline to 4.9–16.4%; and the pre-intervention underweight (43%) will decline to 1.2%–21.3% under three alternative regression scenarios (Tables 3–5).
- 4. If KMNPP transitions of five years are applicable to all the households in the poorest two quintiles of 112 aspirational districts, after five years of intervention: 54.8% children aged 6–35 months will be normal (without stunting, without wasting and without underweight) as against pre-intervention level of 37.5% (Table 6).
- 5. Due to the impact of KMNPP interventions in two lowest wealth quintile households of 112 aspirational districts, in all the 112 aspirational districts, the pre-intervention levels of 41.7% stunting, 22.8% wasting and 38% underweight will reduce to average indicators of 33.6%, 15.5% and 20.7%, respectively. Consequently, in the national average of all the 707 districts of India, the pre-intervention levels of 36.2% stunting, 19.9% wasting and 31.2% underweight will reduce to 31.4%, 16.1% and 23.5%, respectively (Table 6).

# Comparability of Our Results with Other Studies

To the best of our knowledge, even after a detailed search, we have not been able to find a comparable study which has projected future improved CGF measures calculated in any geography on the basis of real-time data resulting from actual implementation of inter-sectoral interventions, as were implemented through KMNPP.

'Projecting stunting and wasting under alternative scenarios in Odisha, India, 2015–2030: a Lives Saved Tool (LiST)-based approach', is a study which attempts to model the stunting and wasting in the state of Odisha, India by scaling up maternal and child health interventions under alternative scenarios. The LiST (Lives Saved Tool) software is used to model the nutritional outcomes and prioritise interventions, based on four alternative hypothetical scenarios (Mishra et al., 2019). KMNPP interventions and outcomes were not derived from a desk modelling exercise. Inter-sectoral interventions were actually implemented among the two lowest quintile households with 100% coverage in the two most backward Blocks of Karnataka and real-time data was obtained by regular monitoring, which provided evidence of significant improvement of all the three CGF measures.

### Rationale for Using Three Regression Scenarios

Using stunting levels of children during 2000–2022 and for projecting future levels by 2030 by different countries including India, UNICEF/WHO/World Bank in its joint child malnutrition estimates used linear regression and projected future levels using slope/annual average rate of reduction, as the basis (UNICEF/WHO/WB). In a multi-country analysis of child nutrition and income, scatter plots and regression lines of each child indicator against the natural log of real income were used, as this approach transforms exponential relationships into linear ones, on the lines of logarithmic regression used by us. Logarithmically transforming variables in a regression model is a very common way to handle situations where a non-linear relationship exists between the independent and dependent variables. Using the logarithm of variables makes the effective relationship non-linear, while still preserving the linear model and is a convenient means of transforming highly skewed variables into ones that are more approximately normal. We have also fitted exponential regression lines as there may be situations when CGF measures may decline rapidly initially and then there is a sudden deceleration of decline later! For KMNPP variables, changes in three CGF measures in all three regressions fitted well with  $R^2$  value/variance explained by the fitted equations ranging from 71% to 83%, particularly high for wasting (77%–83%). This implies that the regression fits using three alternate scenarios are robust, and provide scope for policymakers to choose one of the three scenarios keeping in view the historical trends in decline in these three measures.

However, among the three regression equations,  $R^2$  value is maximum for all the three CGF measures when linear regression trend is used, as compared to exponential and logarithmic regression trends. Hence, based on  $R^2$  value, out of the three regression scenarios, we recommend linear regression for prediction of CGF measures in other geographies of India.

### Strengths and Limitations

This study, to the best of our knowledge, has projected for the first time how the three CGF measures for 6–35 months old children among the two poorest quintile households of the ADs will improve if the interventions of the KMNPP are implemented for five years with the same robustness; how they will positively impact the CGF measures of the 112 ADs as a whole; and how they will further impact positively the national average for all the 707 districts of India.

Perhaps, for the first time, calculations for the three types of regression analyses—linear, exponential and logarithmic, are based on the rate of improvements which occurred in underweight, wasting and stunting among children aged 6–35 months, which also factor in the transitions that took place within these three measures, while the interventions were in progress.

One of the limitations of our study is that our regression estimates are based on only seven data points of CGF measures in KMNPP during only three years of interventions, and the future projections are modelled on them.

Another limitation is that we could not validate the regression trends noticed in KMNPP with similar datasets from other parts of India due to non-availability of programs/interventions similar to that of KMNPP.

# Conclusion

This study clearly establishes that there is significant reduction of three CGF measures of stunting, wasting and underweight if the multi-sectoral and intergenerational KMNPP interventions are implemented for a period of five years in the same robust manner covering all children 6–35 months among the two lowest quintile households in the 112 AD.

These multi-sectoral interventions directly target the root causes of undernutrition and micronutrient deficiency by:

- Addressing the information deficit among families and communities and bringing about behaviour change through effective and sustained grassroots IEC campaigns, particularly at family level and providing knowledge and awareness about proper nutrition practices, proper child, adolescent and maternal nutritional care, and creating demand for on-going nutrition, health and sanitation programmes.
- 2. Bridging the calorie-protein micronutrient deficit among target groups by making available affordable fortified, multi-grain nutritious food supplementation for the targeted population.
- Creating actual convergence of nutrition and nutrition-related services at the village and community level by involving community groups like NGOs/SHGs/panchayats, and creating demand through awareness generation.
- 4. Real-time monitoring.

As per the linear regression trend: stunting decreased from 46.3% to 30.4%, wasting decreased from 24.6% to 9.0% and underweight decreased from 43.0% to 1.2%.

As per the exponential regression trend: stunting decreased from 46.3% to 36.4%, wasting decreased by 24.6% to 4.9% and underweight decreased from 43.0% to 11.5%.

As per the logarithmic regression trend: stunting decreased from 46.3% to 38%, wasting decreased by 24.6% to 16.4% and underweight decreased from 43.0% to 21.3%.

Using linear trends and applying them to the poorest two quintile households in the 112 ADs would increase the percentage of normal children (non-stunted, non-wasted and non-underweight) from 37.5% to 54.8% (Table 6).

This would decrease the incidence of stunting in all 112 ADs from 41.7% to 33.6%, wasting from 22.8% to 15.5% and underweight from 38% to 20.7%.

For all 707 districts of India, namely the national average, the incidence of stunting will be reduced from 36.2% to 31.4%, wasting from 19.9% to 16.1%, underweight from 31.2% to 23.5%, in five years from the pre-intervention level (NFHS-5).

Keeping in view the nature of the inter-sectoral interventions, and the fact that the data and assumptions are not laboratory-based or model-based, but are based on real-time field data that captures the improvements in stunting, wasting and underweight among 6–35 months infants after actual implementation of multi-sectoral and dietary interventions covering children, adolescent girls and

mothers, and behaviour change interventions for families and communities, we were of the opinion that the linear regression method would most aptly predict the changes over period of five years, as it takes into account average changes in the dependent variables during period of regression fit.

The article 'Multisectoral Nutrition Interventions and Their Impact on Nutritional Status of Children: An Open Experiment in Two Remote Blocks of Karnataka, India' was published on 19 May 2022 and has been widely read as per the metrics available on the website (Rao et al., 2022). We have so far not received any adverse comments or questions regarding any aspect of the article, including methodology, findings, results and conclusions.

The project interventions were successfully implemented in the most backward blocks of Karnataka, in which the lowest two quintile households have similar indicators as in the ADs, by supplementing and converging with existing government programs. The 'socio-ecological approach' of the intervention design involves family, community, local bodies and governmental agencies as stakeholders in the program. Further, the interventions are extremely doable and actually put into practice several principles that have been advocated by experts over the last few decades, such as the inter-sectoral approach; emphasis on IEC and behaviour change in the household; emphasis not only on exclusive breastfeeding until six months, but also on complementary feeding after six months, the lack and inadequacy of which is the root cause of child undernutrition in India.

Hence, there is strong justification for replication of the project interventions in all the poorest two quintile households of 112 ADs, as these children suffer from chronic child undernutrition. This can reduce stunting by almost 33%, wasting by almost 63% and underweight by 97% in the intervention districts and results in a drop of 19%, 32% and 46% of stunting, wasting and underweight, respectively in the 112 ADs, which results in a drop of 13% stunting, 19% wasting and 25% underweight in India's national average, in five years. These improvements are over and above the improvements which result from ongoing development programmes in India and the general socio-economic progress of the people.

The cost for strengthening our human capital and demographic dividend in the ADs per Block per year through the focused interventions of KMNPP is far less than constructing one kilometre of national highway! This investment in human capital would result in optimal cognitive and physical development of children, our future demographic dividend; higher learning capacity among adolescents, our immediate demographic dividend; and higher acquisition of skills and upward mobility translating to higher earnings and increased national GDP.

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#### Notes

1 RMNCH A—Reproductive, Maternal, Newborn, Child and Adolescents.

- 2 chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://publicnutrition.aurosociety.org/wp-content/ uploads/2025/04/KCNM-STRATEGY-PAPER.pdf
- 3 WHO (2014). Six global nutrition targets that by 2025 aim to achieve a 40% reduction in the number of children under 5 who are stunted; achieve a 50% reduction of anaemia in women of reproductive age; achieve a 30% reduction in low birth weight; ensure that there is no increase in childhood overweight; increase the rate of exclusive breastfeeding in the first six months up to at least 50%; reduce and maintain childhood wasting to less than 5%.
- 4 SDG Target 2.2 | Malnutrition: End all forms of malnutrition, including achieving targets on stunting and wasting in children under five years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women and older persons.
- 5 JME Report (2023, pp. 20 and 21). Three types of regression analyses (UNICEF et al., 2023).

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