J. Indian Inst. Sci.
A Multidisciplinary Reviews Journal
ISSN: 0970-4140 Coden-JIISAD

REVIEW ARTICLE

Ecosystems Determinants of Nutritional Adequacy Among the Indian Preschool Children

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Abstract | Given the specified importance of dietary diversity in reducing the burden of malnutrition, our study explores the reasons for the high rate of malnutrition in India through assessment of a comprehensive range of ecosystem factors leading to poor nutrients intake. The study uses the Dietary Diversity Score (DDS) to investigate preschoolers, through differences in wealth, gender, and health. Demographic and Health Survey (2015–16) data of 1,40,470 preschool children between the ages of 2–5 years, is investigated using the Bronfenbrenner's Ecological Systems Theory. Multiple linear regression models developed to investigate the association between variables, depict the importance of vaccination (p-value < 0.01, 95% CI 0.02–0.06) as positively impacting the outcome measures. Interestingly, overall wealth index does not impact the dietary diversity of the child. The lower wealth index, however, significantly impacts the DDS of the female child as compared to the male child (p-value < 0.1, 95% CI − 0.03 to 0.02), indicating that the lower wealth index plays a role in developing the non-egalitarian gender attitudes for female children. Policy implications involve adapting biofortified foods with higher density of nutrients with major focus on female children to minimize the gender gap and leveraging the digital technology such as telemedicine, and advanced techniques such as artificial intelligence, machine learning, and big data to offer real-time surveillance to address the healthcare needs in the ongoing immunization programs.

Keywords: *Bronfenbrenner ecological systems theory, Dietary diversity, Preschool children, Health, Gender, Wealth index*

1 Introduction

The recent report by UNICEF highlights the high rate of mortality among children under five years. More than half of these early child deaths are attributable to malnutrition, particularly in the case of countries with extreme poverty, gender inequality, lack of access to healthcare, and wide disparities of wealth. Inadequate intake of macronutrients, including proteins, carbohydrates, and fats, which are essential for providing body energy could lead to malnutrition and anaemia in children[18]. For instance, protein-energy deficiency influences physical growth and manifests as undernutrition in forms of underweight (low body weight for certain age), stunting (impaired liner growth), wasting (actual weight loss), and nutritional anemia (Rodriguez et al. 2011). In addition, low-carbohydrate diets may contribute to rapid weight loss due to the restrict kilojoules or energy.

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Besides undernutrition, faulty CF practices and poor diet habits (e.g., excessive sugar intake and processed carbohydrates) also possibly contributes to the increasing trend in overweight or obesity of children[25]. Further, deficiency in macronutrients negatively impacts cognition and emotion, early brain development, and increases susceptibility to diseases across the lifespan[39]. The consumption of diverse diet contains all the major food groups (vegetables, fruits, grains, meat, and dairy products), therefore, is necessary for achieving nutrient adequacy and optimal growth and development.

Although, an increasing number of studies address the issue of child's nutrients dietary inadequacy, a comprehensive assessment of the ecosystems variables leading to the nutrients inadequacy remains limited. The available nutritional data on nutritional health status in Indian suggest the incidence of the burden of malnutrition and the associated health problems among children have reduced rather slowly and not commensurate to the country's economic growth in the last decade[37].

The current study attempts to assess a sample of preschool children from India to identify factors at various ecosystem levels impacting dietary adequacy of children. First, the paper identifies the comprehensive determinants of Dietary Diversity Score (DDS). Second, the paper analyses predictors of DDS through three major subgroups, namely, low and high wealth index, with and without health problems (diarrhoea, fever, and cough), and gender. Third, on basis of the results we suggest policy implications which could play a crucial role in addressing the lower dietary diversity and improve the nutritional status of preschool children in India. The national population-based survey, Demographic and Health Survey (2015–16) is used for the analysis. The data of 1,40,470 preschool children between the ages of 2–5 years in India are investigated using the Bronfenbrenner's Ecological Systems Theory Model.

Given the hierarchical nature of the association of various factors with nutritional status, it is important to examine their effect at the different levels at which they operate. Given the specified importance of dietary diversity feeding practice approach to reduce the burden of malnutrition, our study aims to understand the reasons for the rate of malnutrition being significantly high for India and what is the comprehensive factors leading to the poor nutrients intake. The study employs DDS of a child's diet as a proxy for nutrient adequacy in terms of intake of essential nutrients. The study contributes to the literature by ascertaining the major contributors of DDS among the various sub-groups namely gender (male and female children), wealth index (low and high) and children with health problems (with and without any health problems).

The Bronfenbrenner's ecological systems theory[9] forms the foundational context for the analysis. The theory moves beyond food to identify factors at various environmental levels putting children at higher risk of defective growth and malnutrition. According to Bronfenbrenner[9], a child's surrounding environment plays a significant role in physical growth and further, shaping up a child's nutritional health status[47]. Annexure 1 presents some of the major studies using the theory to study child nutritional health status. The authors identify levels of determinants/influences namely, microsystem, mesosystem, exosystem, macrosystem, and chronosystem level influences on a child's physical growth and development[35]. Although numerous studies demonstrate the range of factors influencing a child's nutritional health status, Bronfenbrenner's ecological systems theory provides a way to analyze the comprehensive ecosystem surrounding the children to identify what might influence their nutritional status[13]. Thus, we investigate the influence factors in overall and context of wealth index, health problems, and sex of children, on a child's dietary diversity intake with the help of Bronfenbrenner's theory.

The paper contains five sections. Section 2 presents the method used for analysis, including the theoretical foundation and data analysis. Section 3 presents the results of the analysis, followed by a discussion on the key findings in Sect. 4. Section 5 presents the conclusion and implications derived from the study.

2 Methods

2.1 Study Design

The study involves a cross-sectional population-based analysis, using the Demographic and Health Survey (DHS) data. The DHS data were collected in the year 2015–2016, in India. The DHS data set includes key information for 2.5 million children from India on 1340 variables, including children's health, nutrition, and demographic indicators including household, maternal characteristics, socioeconomic, environmental conditions, and region of the country, among others. The dataset has one record for every child of interviewed women or caretaker, born in the five years preceding the survey. The study design explores the relationship between dietary diversity score (DDS) and ecosystem variables of preschool children in overall as well as major context of wealth index, health problem and sex of children. Missing values in the data set get included using predictive mean matching which replaces the missing values according to the distribution of each datapoint. In the final analysis, data extracted for preschool children constituting observations on 27 variables for 1,40,470 children in the age range of 2–5 years.

The DHS program utilizes wealth index to indicate inequalities in household characteristics. The wealth index uses expenditure and income measures to create wealth scores for a household. The wealth scores get classified based on the five groups namely poorest, poorer, middle, richer, and richest households. The study combined the poorest and poorer households and build up the group of low wealth index children and combined the richer and richest households and build up the group of high wealth index children.

The current study measured the health problem by the prevalence of any one of the following illnesses in the last 2 weeks before the interview: diarrhoea, fever, and cough. The problem with access to health care measured by if mothers faced any one of the following problems: getting permission to go, getting money needed for treatment, distance to health facility, having to take transport, not wanting to go alone, concern no female health provider, concern no provider, and concern no drugs available, for getting medical help for self. Additionally, as recommended by WHO child's growth standards of the height-for-age (HAZ), weight-for-height (WHZ), and weight for age (WAZ)[45], we classified the data set into the following categories:

- Stunting: height for age < -2 SD of the WHO Child Growth Standards median.
- Wasting: weight for height < -2 SD of the WHO Child Growth Standards median.
- Overweight: weight for height $> +2$ SD of the WHO Child Growth Standards median.
- Underweight: weight for age < -2 standard deviations (SD) of the WHO Child Growth Standards median.
- Overweight: weight for age $> +2$ SD of the WHO Child Growth Standards median.

The DHS measured the anaemia level of a child as follows:

- Mild anaemia: haemoglobin count is between 10.0 and 10.9 g per decilitre (g/dl).
- Moderate anaemia: haemoglobin count is between 7.0 and 9.9 g per decilitre (g/dl).
- Severe anaemia: haemoglobin count is less than 7.0 g per decilitre (g/dl).

Institutional Review Board (IRB) approval was taken from The Demographic and Health Surveys Program (DHSP). We registered at the Program and sought the approval. The registration and approval were granted and allowed for access to the data set and use of the data for statistical reporting and analysis. The approval letter is attached at the end of the manuscript.

2.2 Measures: Dependent Variables

Based on the recommendation of Food and Agriculture Organization of the United Nations (FAO) in guidelines[14], the current study measures an individual's dietary diversity score (DDS), as proxy measures for macro-and micronutrients adequacy of the diet and further classify the following food groups:

- Food groups considered were cereals/roots, vegetables, fruits, legumes/lentils, meat/fish/egg, and milk/dairy products.

Dietary Diversity is defined as the number of different foods or food groups consumed in the previous day. DDS was calculated by summing the number of times a unique food group was consumed during the last 24 h. DDS takes into account a quantity of any food group eaten for the day. In other words, DDS is calculated by considering the number of times a food group gets eaten that day, and not considering the minimum intake for that food group. The DDS ranges from 0 to 6. As an effective indicator of nutritional status, DDS forms the dependent variable in our study.

2.3 Measures: Independent Variables

2.3.1 Bronfenbrenner's Ecological Systems Theory

Bronfenbrenner's ecological systems theory[9] forms the base to understand and organizes the ecosystem variables. The theory classified the child's surrounding environment into five nested levels, namely, the microsystem, the mesosystem, the exosystem, the macrosystem, and the chronosystem.

The microsystem level refers to immediate surroundings and direct contact of a child including family, school, peers, and childcare environments[5]. Factors like maternal health[16], and early child care[38] can describe as the closest and direct contact of a child. Additionally, the general home conditions on water, sanitation, hygiene (WASH)[19], and housing status directly impact child health as well[11].

Mesosystem describes the connection between microsystem factors. In other words, the interrelationship between two or more individuals in the microsystem influencing a child' growth and are salient to children's development[4]. The variables include interaction or association between parents and healthcare facilities, access to the healthcare facilities, and mother's anthropometry such as Body Mass Index (BMI) and height during pregnancy, childbirth and early childhood influencing on child's overall health and development with short-term and long-term consequences[22].

The third level of the system, the exosystem, defines the larger social system and explains the linked among formal and informal social settings. The variables of the exosystem may not interact with the child directly but strongly influence one or more microsystem structures and thus, indirectly affect the child's development (Angela[3]. The exosystem level underlines the importance of community-based family resources and community support such as education, health, nutritional programs, and services for child care activities[20, 30].

Macrosystem, the fourth level, looks at the influence of society and cultural elements such as socioeconomic status, poverty, wealth, and geographic location on a child's development[20, 30]. Geographical location (for example, rural versus urban; hills versus plains), socioeconomic status (for example, low income, low education and social underprivilege) and cultural effects (for example undervaluation of female child, and status of parents in the family) impact child development.

The fifth and final level of the system, the chronosystem level refers to all the major environmental transitions across the childhood growth period[20, 30]. The chronosystem environmental level includes the life transition occurring over the lifetime such as parents' marital status, financial status, parental healthcare challenges and hardship of single parenting which can lead to insufficient care and higher vulnerability towards physical and mental problems[12].

The independent variables are listed in Table 1. The independent variables are categorized as per the theory in Fig. 1.

Observations of 1340 variables for 2.5 lakhs children, from the DHS data set. Out of the 1340 variables in the data set, the present study included 78 variables as relevant for the study. Among children under 5 years, we take observations from 1,40,470 children with age 2–5 years old and removed the rows involving data of children who were not alive at the time of the survey. We have included the missing values in the data set using predictive mean matching which replaces the missing values according to the distribution of each datapoint.

Next, to measure the nutrients adequacy of a child's diet, the current study employed Dietary Diversity Score (DDS) as the indicator for nutritional adequacy and quality of a diet. Among the 78 variables identified from the DHS data set, bivariate correlation analysis led to dropping of variables with significant correlated, to avoid the multicollinearity issues and finally, our dataset for the analysis consists of 27 variables.

2.4 Data Analysis

Multiple linear regression (MLR) analysis models are employed to evaluate the influence of independent variables on DDS of preschool children. The models are developed for high wealth index and low wealth index, children with health problem and children who does not having health problem, and male and female children as three discrete categories to determine the key factors influencing the DDS of children as the dependent variables. Tables 2 and 3 provide the descriptive analysis of the data.

3 Results

Variable characteristics and children DDS of six major food groups are shown in Tables 2 and 3. Approximately 3.30% of male children ($n = 2445$), and 3.20% of female children ($n = 2172$) were consuming all six major food groups including cereals/roots, vegetables, fruits, legumes/lentils, meat/fish/egg, and milk/dairy products (DDS ranges from 0 to 6) in the last 24-hours or previous day.

Table 2 shows close to 30.30% of children who did not consume all the major food groups were in the locations classified as rural by the DHS. Existing evidence suggest the poor state of rural households' dietary adequacy (e.g., the extent of calorie inadequacy ranged from 10 to 50% or

Table 1: Independent variables.

Environmental levels	Independent variables		Nature of variables
Individual characteristics (e.g., sex, health, etc.)	Child's biological characteristics	Sex of child	Categorical
	Child's health status	Health problems (fever, diarrhoea, cough)	Categorical
		Child's anaemia level	Categorical
	Child's anthropometric measurements	Height for age (normal-stunted)	Categorical
		Weight for age (normal-underweight-overweight)	Categorical
		Weight for height (normal-stunted)	Categorical
	Child's nutritional intake	Vitamin A in last 6 months	Categorical
		Taking iron pills sprinkles or syrup	Categorical
		Breastfeeding	Categorical
Microsystem (e.g., family, parents, and immediate environment)	Maternal health status	Maternal Anaemia level	Categorical
	Housing characteristics	Source of drinking water	Categorical
		Types of cooking fuels	Categorical
		Types of toilet facilities	Categorical
		Housing contraction materials (floor, roof, wall)	Categorical
Mesosystem (e.g., relationship among microsystem structures such as parents and health center)	Maternal anthropometry	Weight, height, arm circumference	Numerical
	Access to healthcare	Maternal problem with access to healthcare	Categorical
		Number of antenatal visits	Numerical
		Baby postnatal check-up	Categorical
		Ever had vaccination	Categorical
		Received polio vaccinate (all doses)	Categorical
		Received DPT vaccinate (all doses)	Categorical
Exosytem (e.g., parents experience effect on a child experience)	Social welfare systems	Anganwadi benefits during pregnancy	Categorical
		Child received benefits from Anganwadi/ICDS center	Categorical
		Mother received benefits while breastfeeding from Anganwadi/ICDS center	Categorical
	Education	Mother's education level	Categorical
Macrosystem (e.g., geographic location and wealth status)	Geographical Location	Type of place of residence	Categorical
	Wealth index	Household's cumulative living standard	Categorical
	Maternal socioeconomic	Work status in last 12 months	Categorical
Chronosystem (e.g., life transition such as parents' divorce)	Life transition	Marital status	Categorical

more) which describes the wide variations in the feeding practices between urban and rural areas[24].

Furthermore, the DDS of malnourished children proxied by macronutrients and micronutrients deficiency illustrates the food insecurity and improper feeding practices of a preschool children in households. For instance, close to 27.90% of stunted children, 26.00% of

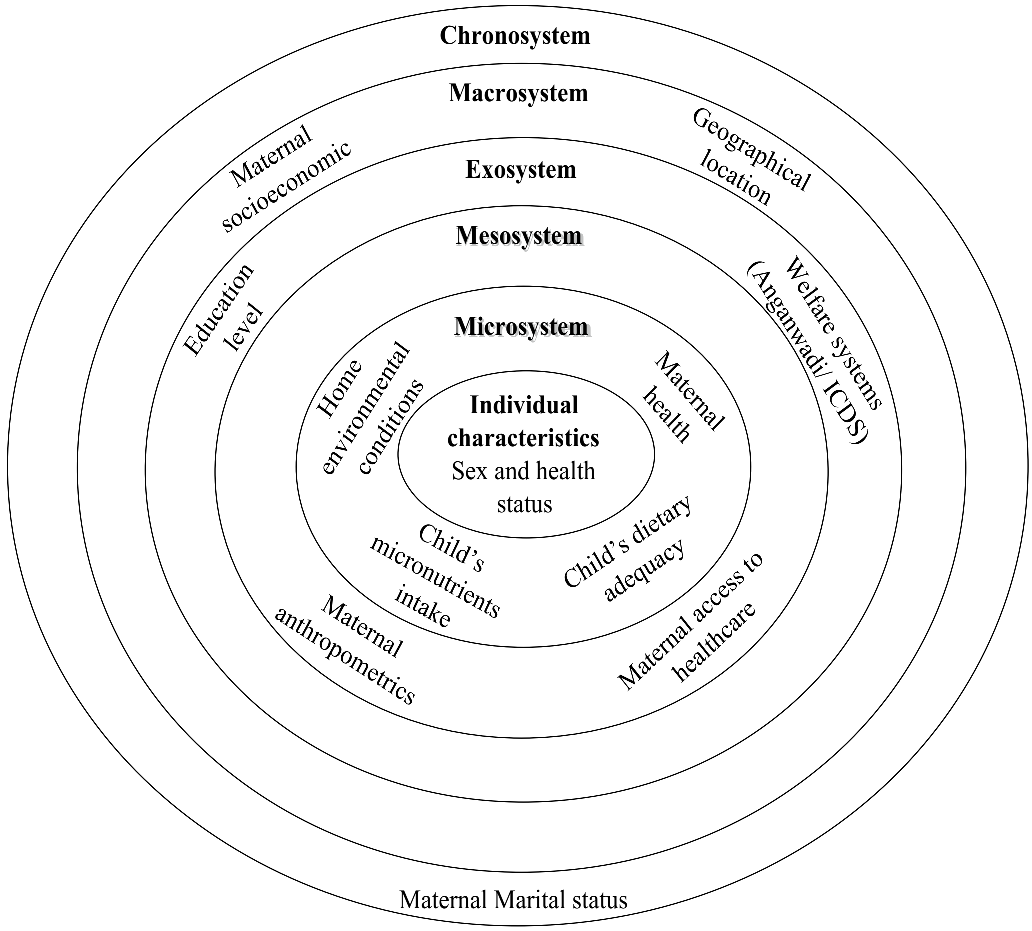


Figure 1: The Ecosystem-based placing of the variables.

wasted children, 26.00% underweight children, and 28.60% of overweight children did not consume all the major food groups. Most notably, 32.20% of children whose mothers' education level is limited at the primary level did not receive any of the major food groups, suggesting the association between lower educational level of mothers and poor feeding practices of children[1].

Table 3 describes that the high percentage (40%) of wasted children belonged to low wealth index households, 17.20% of children faced health problems in terms fever, diarrhoea, and cough, and 35.10% of female children were underweight. Most notably, 81% of children faced access to healthcare are belong to the low and middle wealth index households. These findings signifying the poor states of wealth reduce household's ability to access to healthcare as well as feed adequate and balanced micro-nutrient rich food to children[7].

Table 4 illustrates the results of the regression models. The table describes the linear association between the DDS of children and various factors within the ecological environmental levels listed in Table 4.

We probe this association in two ways, first in the presence of all the variables represented by an Overall model and second, we investigate the interaction of all the factors with various sub-groups of children through DDS. These sub-groups include wealth index (low and high), health problems in terms of diarrhoea, fever, and cough (no/didn't face and yes/faced), and gender (male and female). In all the models, we focus on factors with odds ratio greater than 1.0, which reflects a greater likelihood of having the outcomes.

Polio vaccine plays a positive significant role in DDS of children (p-value < 0.01, 95% CI 0.02–0.06). Sufficient herd immunity, which can be established by adequate vaccination rates, is required to prevent person-to-person transmission of infectious diseases which may cause

Table 2: Descriptive statistics.

Variables characteristics	DDS: Consumption of none of the major food group in percentage (%)	Consumption of 1 major food group in percentage (%)	Consumption of 2 major food groups in percentage (%)	Consumption of 3 major food groups in percentage (%)	Consumption of 4 major food groups in percentage (%)	Consumption of 5 major food groups in percentage (%)	Consumption of 6 major food groups in percentage (%)
Sex of child							
Male	29.20	20.10	18.70	14.30	9.30	5.00	3.30
Female	29.00	20.30	18.90	14.40	9.30	4.80	3.20
Health problems (fever, diarrhoea, cough) Yes	24.60	20.60	20.00	15.40	10.00	5.50	3.80
Wealth index							
Poorest	29.80	19.60	18.70	14.20	9.40	5.00	3.30
Poorer	29.20	20.10	18.90	14.70	9.10	4.70	3.40
Middle	28.90	20.60	18.90	14.30	9.30	4.90	3.10
Richer	29.10	20.30	18.50	14.50	9.50	5.00	3.20
Richest	28.20	20.80	19.30	14.00	9.40	5.00	3.40
Faced problem with access to healthcare	29.90	20.20	18.60	14.10	9.20	4.80	3.20
Taken Polio vaccination	28.60	20.20	19.10	14.40	9.40	5.00	3.40
Taken DPT vaccination	28.90	20.10	18.90	14.40	9.30	5.00	3.30
Child's anaemia level							
Severe	25.10	20.20	20.30	15.60	9.70	5.60	3.50
Moderate	27.80	20.10	19.10	14.90	9.70	5.10	3.30
Mild	29.00	20.00	18.50	14.40	9.60	5.00	3.40
Not anaemic	29.90	20.30	18.70	14.00	9.00	4.80	3.20

Table 2: (continued)

Variables characteristics	DDS						
	Consumption of none of the major food group in percentage (%)	Consumption of 1 major food group in percentage (%)	Consumption of 2 major food groups in percentage (%)	Consumption of 3 major food groups in percentage (%)	Consumption of 4 major food groups in percentage (%)	Consumption of 5 major food groups in percentage (%)	Consumption of 6 major food groups in percentage (%)
Type of place of residence							
Urban	25.50	20.50	19.70	14.40	10.40	5.70	3.80
Rural	30.30	20.10	18.50	14.30	9.00	4.70	3.10
Height for age							
Stunted	31.10	20.30	18.10	13.70	9.10	4.70	3.20
Weight for height							
Wasted	28.80	20.40	18.70	14.70	9.30	4.80	3.40
Weight for age							
Underweight	30.60	20.40	18.30	13.80	9.10	4.70	3.20
Overweight	26.00	19.60	20.10	15.30	10.10	5.30	3.60
Mother education level							
No education	32.20	20.90	18.90	13.90	8.00	3.80	2.40
Primary	29.70	20.20	19.20	14.70	8.70	4.60	2.80
Secondary	27.80	19.70	18.50	14.40	10.10	5.60	3.90
Higher	24.20	19.80	19.60	14.90	11.20	6.10	4.20

Table 3: Descriptive statistics

Variables characteristics	Wealth index in percentage (%)					Health problems in percentage (%)		Gender in percentage (%)	
	Poorest	Poorer	Middle	Richer	Richest	No	Yes	Male	Female
Child's anaemia level									
Severe	1.10	1.20	1.20	1.20	1.10	1.20	1.10	1.20	1.10
Moderate	22.70	22.20	22.50	23.10	23.30	22.60	23.10	22.60	22.80
Mild	26.10	25.90	25.90	26.00	25.60	25.80	26.20	26.00	25.90
Not anaemic	50.10	50.70	50.40	49.70	49.90	50.40	49.60	50.20	50.20
Height for age									
Stunted	40.00	38.70	39.70	39.20	39.10	39.50	39.10	39.40	39.40
Weight for height									
Wasted	16.80	16.80	17.00	16.90	16.10	16.70	17.20	16.80	16.80
Weight for age									
Underweight	35.50	34.80	35.00	34.80	34.30	34.90	35.00	34.80	35.10
Overweight	6.60	6.60	6.60	6.80	6.50	6.50	7.00	6.60	6.60
Faced problem with access to healthcare									
Yes	81.00	81.10	81.00	79.90	79.30	80.60	80.70	80.70	80.50
Type of place of residence									
Rural	23.80	23.50	23.70	23.80	24.20	23.90	23.40	23.90	23.70
Urban	76.20	76.50	76.30	76.20	75.80	76.10	76.60	76.10	76.30
Mother education level									
No education	31.90	31.60	30.50	31.00	30.80	32.00	28.80	31.20	31.30
Primary	14.70	14.70	14.80	14.70	14.20	14.40	15.60	14.50	14.80
Secondary	44.20	44.70	45.20	45.30	45.50	44.40	46.40	44.90	44.90
Higher	9.30	9.00	9.50	9.00	9.50	9.20	9.20	9.50	9.00

diversion of nutrients for the immune response, poor appetite and low dietary intake[15].

Our study highlights the finding of specific differences in low and high wealth index of the household highlights no differences in the impact of various ecosystems due to wealth. This implies the inequality of wealth index does not form a major differentiator in DDS of children and may not be an appropriate indicator of dietary adequacy and diversity. However, the gender model depicts that the lower wealth index negatively impacts on DDS of female children in poorer wealth index (p-value < 0.1, 95% CI − 0.03 to 0.02) and middle wealth index (p-value < 0.1, 95% CI − 0.05 to 0.01) households. Most notably, the findings show that the maternal work status (in last 12 months) does not attempt to narrow down the non-egalitarian gender gap, as the results reveal a positive impact of mother work status (p-value < 0.05, 95% CI 0.00–0.12) on DDS of male children.

Our results confirm the prevalence of anaemic condition at moderate level (p-value < 0.05, 95% CI − 0.17 to 0.00) and mild level (p-value < 0.01, 95% CI − 0.24 to 0.08) (emerged as a strong negative contributor to the dietary adequacy or DDS. Notably, our results highlight the negative impact of anaemia at severe level (p-value < 0.05, 95% CI − 0.14 to 0.02) on female children. This is in line with previous studies inferring the ender inequality plays an important role in skewing the distribution of food against the female child[28]. Further, deficiency in food nutrients increases the prevalence of anaemia is followed by loss of appetite in female children. Surprisingly, child's health problem including diarrhoea, fever and cough (in last 12 days) has positive significant influence (p-value < 0.01, 95% CI 0. 0.13–0.18) on DDS of children which might be due to the better

Table 4: Regression analysis results for DDS of children age between 2–5 years or preschool children

Independent variables	Overall	95% CI	Wealth index		Health problem		Gender	
			High	Low	Yes	No	Male	Female
Child's individual characteristics								
Sex of child (male–female[a])	− 0.010	− 0.03 to 0.01	0.002	− 0.014	− 0.023	− 0.007	0.00	0.00
Health problems (diarrhoea, fever, cough) (yes–no[a])	0.155***	0.13 to 0.18	0.152***	0.155***	0.00	0.00	0.160***	0.149***
Child anaemia level (severe–not anaemic[a])	− 0.056	− 0.14 to 0.02	− 0.058	− 0.027	0.073	− 0.091**	0.000	− 0.121**
Child anaemia level (moderate–not anaemic[a])	− 0.085**	− 0.17 to 0.00	− 0.083	− 0.054	0.046	− 0.122***	− 0.062	− 0.117*
Child anaemia level (mild–not anaemic[a])	− 0.158***	− 0.24 to 0.08	− 0.160**	− 0.129**	− 0.038	− 0.193***	− 0.115**	− 0.213***
Height for age (stunted–normal[a])	0.007	− 0.02 to 0.03	0.016	− 0.012	0.004	0.008	0.001	0.012
Weight for age (underweight–normal[a])	0.091	0.01 to 0.17	0.050	0.112**	0.061	0.104**	0.039	0.151***
Weight for age (overweight–normal[a])	0.001**	− 0.02 to 0.03	0.004	− 0.003	0.012	− 0.002	0.005	− 0.001
Weight for height (wasted–normal[a])	0.008	− 0.06 to 0.08	0.068	− 0.017	− 0.009	0.012	0.060	− 0.047
Weight for height (overweight–normal[a])	− 0.019	− 0.04 to 0.01	− 0.022	− 0.016	− 0.032	− 0.014	− 0.026	− 0.008
Taking iron pills sprinkles or syrup (yes–no[a])	0.024**	0.00 to 0.05	− 0.006	0.036**	− 0.022	0.034***	0.020	0.025
Vitamin A in last 6 months (yes–no[a])	− 0.056***	− 0.08 to − 0.04	− 0.069***	− 0.056***	− 0.023	− 0.067***	− 0.056***	− 0.060***
Breastfed (yes–no[a])	0.067***	0.04 to 0.10	0.074**	0.074***	0.068*	0.065***	0.056***	0.076***
Microsystem environmental level								
Maternal anaemia level (severe–not anaemic[a])	0.008	− 0.08 to 0.10	0.001	0.044	0.113	− 0.017	0.029	− 0.013

Table 4: (continued)

Independent variables	Overall	95% CI	Wealth index		Health problem		Gender	
			High	Low	Yes	No	Male	Female
Maternal anaemia level (moderate–not anaemic[a])	− 0.046	− 0.13 to 0.04	− 0.084	− 0.004	0.040	− 0.067	− 0.020	− 0.073
Maternal anaemia level (mild–not anaemic[a])	− 0.039	− 0.12 to 0.05	− 0.066	0.002	0.017	− 0.052	− 0.017	− 0.062
Source of drinking water (dug well–piped water[a])	− 0.088***	− 0.11 to − 0.07	− 0.082***	− 0.093***	− 0.100***	− 0.084***	− 0.077***	− 0.099***
Source of drinking water (water from spring–piped water[a])	0.009	− 0.03 to 0.04	0.003	− 0.004	0.069*	− 0.008	0.025	− 0.008
Type of cooking fuel (solid fuels–clean fuels[a])	− 0.311***	− 0.06 to − 0.43	− 0.332***	− 0.297***	− 0.490***	− 0.260***	− 0.302***	− 0.317***
Type of toilet facility (unimproved–improved[a])	− 0.034***	− 0.02 to − 0.04	− 0.040**	− 0.033**	− 0.006	− 0.043***	− 0.028*	− 0.041***
Main floor material (rudimentary floor–natural floor[a])	0.048**	0.01 to 0.08	0.080**	0.036	− 0.003	0.059***	0.058*	0.036
Main floor material (finished floor–natural floor[a])	0.136***	0.11 to 0.16	0.130***	0.143***	0.144***	0.132***	0.121***	0.153***
Main roof material (rudimentary roofing–natural roofing[a])	− 0.086***	− 0.14 to − 0.04	− 0.131***	− 0.063*	− 0.180***	− 0.059**	− 0.082**	− 0.090**
Main roof material (finished roofing–natural roofing[a])	− 0.022	− 0.05 to 0.01	− 0.043	− 0.004	− 0.064*	− 0.009	− 0.006	− 0.038
Main wall material (rudimentary walls–natural walls[a])	0.006	− 0.03 to 0.04	0.037	0.006	− 0.004	0.010	0.005	0.007
Main wall material (finished walls–natural walls[a])	− 0.064***	− 0.09 to − 0.04	− 0.052**	− 0.054***	− 0.079***	− 0.060***	− 0.052***	− 0.078***
Mesosystem environmental level								

Table 4: (continued)

Independent variables	Overall	95% CI	Wealth index		Health problem		Gender	
			High	Low	Yes	No	Male	Female
Maternal height (cm)	0.001***	0.00 to 0.00	0.001***	0.001***	0.001***	0.001***	0.001***	0.001***
Maternal weight (kg)	<0.01***	0.00 to 0.00	<0.01**	<0.01	<0.01**	0.000**	<0.01*	<0.01**
Arm circumference	0.017***	0.01 to 0.02	0.017***	0.016***	0.018***	0.016***	0.019***	0.014***
Problem with access to healthcare (yes–no[a])	− 0.033***	− 0.06 to − 0.01	− 0.029	− 0.030*	0.001	− 0.042***	− 0.027*	− 0.040**
Number of antenatal visits during pregnancy (yes–no[a])	0.008***	0.01 to 0.01	0.009***	0.009***	0.006***	0.009***	0.008***	0.008***
Baby postnatal check within 2 months (yes–no[a])	0.027***	0.01 to 0.05	0.040**	0.016	0.037*	0.022**	0.015	0.036***
Ever had vaccination (yes–no[a])	0.354***	0.32 to 0.38	0.334***	0.386***	0.333***	0.357***	0.343***	0.364***
DPT (yes–no[a])	− 0.058***	− 0.0 to 0.03	− 0.078***	− 0.028	− 0.041	− 0.064***	− 0.042**	− 0.078***
Polio (yes–no[a])	0.041***	0.02 to 0.06	0.045**	0.046***	0.059*	0.036**	0.034**	0.049***
Exosytem environmental level								
Child benefited from Anganwadi/ICDS centre (yes–no[a])	0.192***	0.17 to 0.21	0.158***	0.219***	0.195***	0.190***	0.184***	0.199***
During pregnancy benefited from Anganwadi/ICDS centre (yes–no[a])	− 0.117***	− 0.14– − 0.09	− 0.082***	− 0.145***	− 0.076***	− 0.132***	− 0.113***	− 0.123***
While breastfeeding benefited from Anganwadi/ICDS centre (yes–no[a])	0.097***	0.07 to 0.12	0.094***	0.111***	0.038	0.118***	0.100***	0.095***
Mother education level (primary–no education[a])	0.042***	0.01 to 0.07	0.031	0.036*	0.013	0.051***	0.046**	0.037*
Mother education level (secondary–no education[a])	0.128***	0.11 to 0.15	0.147***	0.109***	0.143***	0.124***	0.144***	0.112***
Mother education level (higher–no education[a])	0.226***	0.19 to 0.26	0.234***	0.201***	0.267***	0.215***	0.249***	0.200***
Macrosystem environmental level								

Table 4: (continued)

Independent variables	Overall	95% CI	Wealth index		Health problem		Gender	
			High	Low	Yes	No	Male	Female
Type of place of residence (rural–urban[a])	− 0.057**	− 0.08 to − 0.03	− 0.073***	− 0.063***	− 0.089***	− 0.049***	− 0.063***	− 0.050***
Wealth index (poorer–poorest[a])	− 0.007	− 0.03 to 0.02	0.00	0.00	− 0.0451*	0.0032	0.013	− 0.029*
Wealth index (middle–poorest[a])	− 0.019	− 0.05 to 0.01	0.00	0.00	− 0.0338	− 0.0157	− 0.007	− 0.033*
Wealth index (richer–poorest[a])	− 0.010	− 0.04 to 0.02	0.00	0.00	− 0.015	− 0.008	− 0.016	− 0.003
Wealth index (richest–poorest[a])	− 0.004	− 0.03 to 0.02	0.00	0.00	− 0.046	0.007	0.007	− 0.017
Maternal worked in last 12 months (women) (yes–no[a])	0.026	− 0.02 to 0.07	0.018	0.032	0.042	0.017	0.062**	− 0.018
Chronosystem environmental level								
Marital status (never married nor lived in a consensual union–legally or formally married[a])	0.220*	− 0.02 to 0.46	0.099	0.065	0.073	0.275*	0.271	0.183
Marital status (not formally married but living with a man/woman in a consensual union–formally married[a])	0.191	− 0.06 to 0.44	0.041	0.028	0.153	0.213	0.261	0.130
Marital status (widowed–formally married[a])	0.064	− 0.23 to 0.35	− 0.058	− 0.047	0.160	0.056	0.159	− 0.017
Marital status (divorced–formally married[a])	0.134	− 0.13 to 0.40	0.128	0.001	− 0.023	0.189	0.149	0.125

CI confidence interval; significance determined at $p < 0.1$; ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

[a] Represents reference level

nutritional healthcare of child's caretakers during a child's illness.

Our results highlight that housing status plays a significant role in influencing the DDS of child. The standard housing construction such as rudimentary (p-value < 0.05, 95% CI 0.01–0.08) and finished (p-value < 0.01, 95% CI 0.11–0.16) floors get positively associated with the DDS, protecting a child from allergic, respiratory, neurological, and infectious illness which reduce the dietary intake[23]. On the contrary, household source of dug well drinking water (p-value < 0.01, 95% CI − 0.11 to − 0.07), unimproved type of toilet facility (p-value < 0.01, 95% CI − 0.02 to − 0.04), and solid cooking fuels (p-value < 0.01, 95% CI − 0.06 to − 0.43) negatively influence on DDS of children.

Maternal lack of access to healthcare services due to barriers such as getting permission to go, money for treatment, and distance to health, and not wanting to go alone, among others are major causes of delay to diagnose, prevent, and treatments of health issues of mother and child[46], and negatively contributes to low DDS of child (p-value < 0.01, 95% CI − 0.06 to − 0.01). Our results confirm the same. Additionally, increase in number of antenatal visits during pregnancy (p-value < 0.01, 95% CI 0.01–0.01), and baby postnatal care (p-value < 0.01, 95% CI 0.01–0.05) positively influence on DDS of children. Mother's primary level of education positively impact (p-value < 0.1, 95% CI 0.00–0.07) on DDS of children in low wealth index (p-value < 0.01, 95% CI 0.02–0.08), and children with health problems (p-value < 0.01, 95% CI 0.02–0.08). Our results confirm the role of mother's height (p-value < 0.01, 95% CI 0.00–0.00), weight (p-value < 0.01, 95% CI 0.00–0.00) on DDS of child.

Adding to the relationship between anaemia level and DDS, the study reaffirms a significant positive association that exists between the iron intake and DDS (p-value < 0.05, 95% CI 0.00–0.05), particularly in DDS of low wealth index children (p-value < 0.05, 95% CI 0.00–0.07), and children who did not faced health problem (p-value < 0.01, 95% CI 0.01–0.06). Reason being, regular iron consumption prevents a child from anaemia which could adversely affect the dietary intake and reduce the DDS (Erdman et al. [2012]). In overall, results confirm the Anganwadi/ICDS centre benefits among children (p-value < 0.01, 95% CI 0.17–0.21) and breastfeeding mothers (p-value < 0.01, 95% CI 0.07–0.12) positively impact on DDS of children, through contributes to accessible nutrients food intake. Additionally, the health model depicts that the ICDS benefits of breastfeeding mothers (p-value < 0.01, 95% CI 0.07–0.12) certainly impacts on DDS of children who did not face any health issues.

4 Discussion

The present paper investigates the ecological factors influencing the dietary diversity of children aged between 2 and 5 years old. The findings present two noteworthy associations with DDS. Importance of vaccination, and the decisive role of low wealth index in dietary diversity of female children. Moreover, the findings reaffirm the existing literature by highlighting the criticality of child's health status, housing status, and maternal access to healthcare in impacting the dietary adequacy of a child.

Vaccination supports better immunization and hence, associated with better nutritional status of children. The results highlight that receiving polio vaccination is positively associated with dietary diversity of a child. Polio vaccination prevents a child from nutritional diseases (e.g., decreased appetite, nausea, fever, and abdominal pain) and improve their overall health. India is a principal producer and exporter of vaccines, but still, it is home to one-third of the world's under-five children with no immunization[43]. The insufficient vaccine coverage could be attributed to the parental vaccine hesitancy with common concerns including uncertainty about the need for vaccination and questions about vaccine safety and efficiency[10]. According to UNICEF, in India, alongside with operational challenges in delivering vaccines to the country's 1.38 billion people, vaccine hesitancy remains a barrier, which led to a resurgence of diseases and further, reduce the appetite and nutrients intake. Additionally, the existing literature highlights the gender discrimination, disfavouring female child as an important determinant of childhood vaccination in India[31].

Another noteworthy result is the inequality of wealth index does not form a major differentiator in dietary diversity of children and may not be an appropriate indicator of dietary adequacy and diversity. This result confirms the report released by the State of the World's Children under UNICEF, stating that irrespective of wealth index the children in India experience poor nutritional status and inappropriate dietary intake[40]. However, probing deeper into the results we find that The DDS of female children is significantly lower that of male children in the low wealth index households. Existing literature suggests poverty in developing countries including India is associated with non-egalitarian gender attitudes such as son preference and better nutritional care of male as compared to female children[32]. This may be one of the leading causes of better dietary diversity of male as compared to female children in these populations. Most remarkably, the results suggest a positive association between the maternal work status (in last 12 months) and dietary diversity of male children indicate increasing purchasing ability of a mother towards diverse nutritional foods also does not narrow the gender gap in terms of nutritional status[17].

Furthermore, the findings also confirm the context of gender inequality due to the higher prevalence of anaemia at severe level in female children as compared to male children. Existing evidence have reported discrimination in diet diversity, complementary feeding practices, basic amenities, and healthcare against the girl child in India[8]. The inadequate feeding practices and healthcare of female children is one of the leading causes in prevalence of anaemia and further significant changes towards a decrease in appetite and dietary intake and apparent in coverage of full and no immunization in female children[34]. Our study reaffirms the same.

In addition to the findings related to anaemia in children, we find the negative association between housing status (a reflector of wealth) including solid cooking fuels and dietary diversity of a child with health problem. Research shows the indoor air pollution as a result of biomass fuel (wood, charcoal, dung, and agricultural residues) use in cooking in households is a major environmental cause of anaemia[26], and resulting chronic health issues including respiratory infections, chronic lung diseases, prevalence of stunting growth, and about 30% higher mortality rates among Indian children[41]. Our findings confirm the same.

Last, the findings indicate problems with access to healthcare adversely impacting the dietary diversity of a child. Existing evidence, particularly in the context of India, shows the high prevalence of morbidity and mortality, and the existence of significant barriers to access healthcare services, particularly for women. These barriers include problems with access to healthcare facilities rooted in gender discrimination such as forced to ask permission or ask money from the spouse to go for healthcare facilities for herself or child [29]. These barriers are even more prominent in rural areas with lower levels of education in India.

5 Conclusion and Policy Implications

The several significant ecosystems variables highlight the need for large scale intervention for the preschool children. For example, the low impact of wealth index, the high negative impact of low wealth index on DDS of female children, and the fact that maternal occupation does not narrow down the gender gap that demonstrates the social dynamics of gender disparity in India.

In view of the gender gap in dietary diversity of Indian preschool children, our study brings out the need to introduce a modern nutritional approach, independent of the social dynamics of wealth and occupational status. Using biofortification which involves breeding higher amounts of vitamins and minerals directly into staple foods and further improving the nutritional value of the stable food. These staple crops include bean, cassava, orange sweet potato, rice, maize, pearl millet, and wheat. Adapting the biofortified foods with higher density of nutrients with major focus on female children through a larger platform such as government schemes (e.g., Anganwadi/ICDS) could contribute to prevention of poor nutritional health status of girls and minimize the gender gap.

Biofortified crops have been developed via conventional breeding or genetic engineering. Genetic engineering enables simultaneous augmentation of multiple micronutrients, along with improving the post-harvest stability of vitamins, whilst also including agronomically important traits, such as enhanced yield and stress resilience. Besides, in the last few years, the cost-effectiveness and feasibility of implementing biofortification using conventional breeding techniques has been established as a key intervention to reduce mineral and vitamin deficiencies in developing countries. Likewise, in context of India, the biofortification such as iron-rich staple foods (e.g., iron-rich rice and wheat varieties) has successfully resulted in prevention of nutritional diseases such as anaemia (Finkelstein et al. 2015; Stein et al. 2008).

Furthermore, the problem of maternal access to healthcare can be countered through technology. In the context of global health, technology's potential to support equitable, affordable, and effective health care systems is endless. This intersection between technology and health, 'digital health', has to potential to bring broad range of digital health solutions on the doorstep of the mother. For instance, in a very timely intervention, the government of India released Telemedicine practice guidelines for Registered Medical Practitioners on March 25, 2020, amid the COVID-19 outbreak (National TeleConsultation Service Ministry of Health and Family Welfare 2020).

Telemedicine is the delivery of healthcare services from a distance and considered to be the remote diagnosis and treatment of patients by means of telecommunications technology, thereby providing substantial healthcare to low-income regions. Evidence suggested use of telemedicine services could be a viable and cost-effective option to ensure adherence to evidence-based medicine and standardisation of care in resource limited countries such as India (Venkatesh et al. 2022).

Furthermore, to stay ahead of the curve in demand for healthcare services and solutions, organizations worldwide are turning to advanced techniques such as artificial intelligence (AI), machine learning (ML), and big data. The application of AI through (ML) and natural language processing (NLP) can bring a tremendous amount of value across the current healthcare continuum to the delivery of improved outcomes. The use of these technologies in healthcare will also help support new models of "value-based care" as these technologies can be leveraged to drive more personalization and transformation in healthcare to patients.

Our study highlights the ecosystems determinants of the nutritional status of the preschool children of India and advocates for use of technology like digital health platforms for the solution of the same. For example, using digital health and bio fortification under the umbrella of large nutritional health schemes such as Anganwadi services could be an effective approach to provide accessible nutritional healthcare for mothers and children. For instance, improving the use of technology within nutritional health schemes (such as data on smartphones) will result in real-time accessibility to healthcare services particularly for mothers. In addition to the timely healthcare facilities, the digital health platforms can be employed to provide primary healthcare information regarding antenatal care, postnatal care, breastfeeding monitoring, dietary intake and vaccination reminder.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Acknowledgements

The authors would like to acknowledge the United States Agency for International Development (USAID) and Ministry of Health and Family Welfare, Government of India for providing access to the Demographic and Health Survey (DHS) (also known as NFHS-4), conducted in India. This research is funded by a grant from the Akshaya Patra Foundation, India (Grant number SP/APRL-19-0001).

Funding

Funding was provided by Akshaya Patra Foundation, India (Grant number SP/APRL-19-0001).

Supplementary Information

Below is the link to the electronic supplementary material.Supplementary file1 (DOCX 21 KB)

Received: 26 August 2022 Accepted: 26 August 2022
Published: 16 September 2022

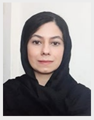
References

1. Adnan N, Muniandy ND (2012) The relationship between mothers' educational level and feeding practices among children in selected kindergartens in Selangor, Malaysia: a cross-sectional study. Asian J Clin Nutr 4(2):39–52. https://doi.org/10.3923/ajcn.2012.39.52
2. Alderman H, Headey D (2018) The timing of growth faltering has important implications for observational analyses of the underlying determinants of nutrition outcomes. PLoS ONE 13(4):1–16. https://doi.org/10.1371/journal.pone.0195904
3. Oswalt A (2021) Child & adolescent development: overview Urie Bronfenbrenner and child development. Gulf Bend Center. https://www.gulfbend.org/poc/view_doc.php?type=doc&id=7930. Accessed 17 Aug 2021
4. Ashiabi GS, O'Neal KK (2015) Child social development in context: an examination of some propositions in Bronfenbrenner's bioecological theory. SAGE Open. https://doi.org/10.1177/2158244015590840
52. Bajpai N, Wadhwa M (2021) National Teleconsultation Service in India: eSanjeevani OPD ICT India Working Paper 53. India
5. Berk LE (2002) Child development, 5th edn. Allyn and Bacon, Boston
6. Bhargava SK, Chellani H, Dadhich JP (2009) National Neonatology Forum (NNF): role in mainstreaming newborn health in India. J Neonatol 23(3):183–190. https://doi.org/10.1177/0973217920090302
7. Black RE, Allen LH, Bhutta ZA, Caulfield LE, de Onis M, Ezzati M, Mathers C, Rivera J (2008) Maternal and child undernutrition: global and regional exposures and health consequences. Lancet 371(9608):243–260. https://doi.org/10.1016/S0140-6736(07)61690-0
8. Borooah VK (2004) Gender bias among children in India in their diet and immunisation against disease. Soc Sci Med 58(9):1719–1731. https://doi.org/10.1016/S0277-9536(03)00342-3
9. Bronfenbrenner U (1979) The ecology of human development. Harvard University Press, Cambridge. https://khoerulanwarbk.files.wordpress.com/2015/08/urie_bronfenbrenner_the_ecology_of_human_developbokos-z1.pdf. Accessed 12 Mar 2022

10. Cataldi JR, O'Leary ST (2021) Parental vaccine hesitancy: scope, causes, and potential responses. Curr Opin Infect Dis 34(5):519–526. https://doi.org/10.1097/QCO.0000000000000774
11. Dunn JR (2019) Housing and healthy child development: known and potential impacts of interventions. Annu Rev Public Health 41:381–396. https://doi.org/10.1146/annurev-publhealth-040119-094050
12. El-Sheikh M, Cummings EM, Kouros CD, Elmore-Staton L, Buckhalt J (2008) Marital psychological and physical aggression and children's mental and physical health: direct, mediated, and moderated effects. J Consult Clin Psychol 78(1):1–7. https://doi.org/10.1016/j.trsl.2012.08.005
50. Erdman JW, MacDonald IA, Zeisel SH (2012)Present Knowledge in Nutrition Tenth Edition. Tenth Edit. John W. Erdman Jr., Ian A. Macdonald SHZ, editor. Wiley-Blackwell, A John Wiley & Sons, Ltd., Publication. Present Knowledge in Nutrition Tenth Edition Edited by John W. Erdman Jr. PhD Ian A. Macdonald PhD Steven H. Zeisel MD, PhD A John Wiley & Sons, Ltd., Publication
13. Eriksson M, Ghazinour M, Hammarström A (2018) Different uses of Bronfenbrenner's ecological theory in public mental health research: what is their value for guiding public mental health policy and practice? Soc Theory Health 16(4):414–433. https://doi.org/10.1057/s41285-018-0065-6
14. FAO (2010) Guidelines for measuring household and individual dietary diversity. http://www.fao.org/3/a-i1983e.pdf. Accessed 09 Mar 2021
15. Fine P, Eames K, Heymann DL (2011) "Herd immunity": a rough guide. Clin Infect Dis 52(7):911–916. https://doi.org/10.1093/cid/cir007
51. Finkelstein JL, Mehta S, Udipi SA, Ghugre PS, Luna SV, Wenger MJ, et al. (2015) A randomized trial of ironbiofortified pearl millet in school children in India. J Nutri 145:1576–1581
16. Garbarski D (2014) The interplay between child and maternal health: reciprocal relationships and cumulative disadvantage during childhood and adolescence. J Health Soc Behav 55(1):91–106. https://doi.org/10.1177/0022146513513225
17. Gaudin S (2011) Son preference in Indian families: absolute versus relative wealth effects. # Population Association of America. https://doi.org/10.1007/s13524-010-0006-z
18. Ghose B, Tang S, Yaya S, Feng Z (2016) Association between food insecurity and anemia among women of reproductive age. PeerJ 2016(5):1–12. https://doi.org/10.7717/peerj.1945
19. Gizaw Z, Worku A (2019) Effects of single and combined water, sanitation and hygiene (WASH) interventions on nutritional status of children: a systematic review and meta-analysis. Ital J Pediatr 45(1):1–14. https://doi.org/10.1186/s13052-019-0666-2
20. Guy-Evans O (2020) Bronfenbrenner's ecological systems theory|simply psychology. Simply psychology. https://www.simplypsychology.org/Bronfenbrenner.html. Accessed 16 Jun 2021
21. Habibzadeh F, Chumakov K, Sajadi MM, Yadollahie M, Stafford K, Simi A, Kottilil S, Hafizi-Rastani I, Gallo RC (2022) Use of oral polio vaccine and the incidence of COVID-19 in the world. PLoS ONE 17(3 March):1–12. https://doi.org/10.1371/journal.pone.0265562
22. Hamel C, Enne J, Omer K, Ayara N, Yarima Y, Cockcroft A, Andersson N (2015) Childhood malnutrition is associated with maternal care during pregnancy and childbirth: a cross-sectional study in Bauchi and cross river states, Nigeria. J Public Health Res 4(1):58–64. https://doi.org/10.4081/jphr.2015.408
23. Krieger J, Higgins DL (2002) Housing and health: time again for public health action. Am J Public Health 92(5):758–768. https://doi.org/10.2105/AJPH.92.5.758
24. Lakshmi AJ, Khyrunnisa B, Saraswathi G, Jamuna P (2005) Dietary adequacy of Indian rural preschool children—influencing factors. J Trop Pediatr 51(1):39–44. https://doi.org/10.1093/tropej/fmh072
25. Magriplis E, Michas G, Petridi E, Chrousos GP, Roma E, Benetou V, Cholopoulos N, Micha R, Panagiotakos D, Zampelas A (2021) Dietary sugar intake and its association with obesity in children and adolescents. Children 8(8):1–14. https://doi.org/10.3390/children8080676
26. Mishra V, Retherford RD (2007) Does biofuel smoke contribute to anaemia and stunting in early childhood? Int J Epidemiol 36(1):117–129. https://doi.org/10.1093/ije/dyl234
27. Modjadji P, Molokwane D, Ukegbu PO (2020) Dietary diversity and nutritional status of preschool children in North West Province, South Africa: a cross sectional study. Children 7(10):174. https://doi.org/10.3390/children7100174
28. Modugu HR, Khanna R, Dash A, Manikam L, Parikh P, Benton L, Sharma S, Santwani N, Roy S, Chaturvedi H, Pattanaik SP, Lall MC, Vijay VK, Lakhanpaul M (2022) Influence of gender and parental migration on IYCF practices in 6–23-month-old tribal children in Banswara district, India: findings from the cross-sectional PANChSHEEEL study. BMC Nutr 8(1):1–16. https://doi.org/10.1186/s40795-021-00491-7
29. Moradhvaj N, Saikia N (2019) Gender disparities in health care expenditures and financing strategies (HCFS) for inpatient care in India. SSM Popul Health 9(December 2018):100372. https://doi.org/10.1016/j.ssmph.2019.100372
30. Guy-Evans O (2020) Bronfenbrenner's ecological systems theory|simply psychology. SimplyPsychology. https://www.simplypsychology.org/Bronfenbrenner.html. Accessed 16 Jun 2021
31. Pande RP, Yazbeck AS (2003) What's in a country average? Wealth, gender, and regional inequalities in

immunization in India. Soc Sci Med 57(11):2075–2088. https://doi.org/10.1016/S0277-9536(03)00085-6

32. Patel R, Singh AK, Chandra M, Khanna T, Mehra S (2018) Is mother's education or household poverty a better predictor for girl's school dropout? Evidence from aggregated community effects in rural India. Educ Res Int. https://doi.org/10.1155/2018/6509815
33. Pollard CM, Booth S (2019) Food insecurity and hunger in rich countries—it is time for action against inequality. Int J Environ Res Public Health. https://doi.org/10.3390/ijerph16101804
34. Prusty RK, Kumar A (2014) Socioeconomic dynamics of gender disparity in childhood immunization in India, 1992–2006. PLoS ONE 9(8):1992–2006. https://doi.org/10.1371/journal.pone.0104598
49. Rodriguez L, Cervantes E, Ortiz R (2011) Malnutrition and gastrointestinal and respiratory infections in children: a public health problem. Int J Environ Res Public Health [Internet]. 8(4):1174–205. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3118884/pdf/ijerph-08-01174.pdf
35. Sincero SM (2021) The ecological systems theory by Urie Bronfenbrenner. Explorable. https://explorable.com/ecological-systems-theory. Accessed 22 Jun 2021
36. Savarino G, Corsello A, Corsello G (2021) Macronutrient balance and micronutrient amounts through growth and development. Ital J Pediatr 47(1):1–14. https://doi.org/10.1186/s13052-021-01061-0
37. Singh A (2020) Childhood malnutrition in India. In: Bhattacharya SK (ed) Perspective of recent advances in acute diarrhea. IntechOpen, pp 1–5. https://doi.org/10.5772/intechopen.89701
48. Stein AJ, Meenakshi JV, Qaim M, Nestel P, Sachdev HPS, Bhutta ZA (2008) Potential impacts of iron biofortification in India. Soc Sci Med. 66(8):1797–808
38. Morrissey T (2019) The effects of early care and education on children's health. Health Aff. https://doi.org/10.1377/HPB20190325.519221
39. Taylor RM, Blumfield ML, Ashton LM, Hure AJ, Smith R, Buckley N, Drysdale K, Collins CE (2021) Macronutrient intake in pregnancy and child cognitive and behavioural outcomes. Indian J Publ Health https://doi.org/10.3390/children8050425
40. UNICEF (2019) Children, food and nutrition. https://www.unicef.org/media/60806/file/SOWC-2019.pdf. Accessed 09 Mar 2022
41. Upadhyay AK, Singh A, Kumar K, Singh A (2015) Impact of indoor air pollution from the use of solid fuels on the incidence of life threatening respiratory illnesses in children in India environmental and occupational health. BMC Public Health 15(1):1–9. https://doi.org/10.1186/s12889-015-1631-7
42. USAID (2021) Agriculture and food security|U.S. Agency for International Development. USAID. https://www.usaid.gov/what-we-do/agriculture-and-food-security. Accessed 15 Aug 2021
43. Vaidyanathan R (2019) Immunization coverage among under-five children living along a school student through child-to-child and child-to-parent information, education and communication strategy. Indian J Public Health 63(4):334–340. https://doi.org/10.4103/ijph.IJPH_424_18
53. Venkatesh U, Aravind GP, Velmurugan AA. (2022) Telemedicine practice guidelines in India: Global implications in the wake of the COVID-19 pandemic. World Med Heal Policy 1–11
44. Vir SC, Suri S (2021) The 5th National Family Health Survey of India: a sub-national analysis of child nutrition. ORF occasional paper no. 315, May 2021, Observer Research Foundation, 315. https://www.orfonline.org/wp-content/uploads/2021/05/ORF_OccasionalPaper_315_NFHS5-ChildNutrition.pdf. Accessed 09 Mar 2022
45. WHO (2006) WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: methods and development. World Health Organization
46. WHO (2019) Breaking barriers towards more gender-responsive and equitable health systems. In: WHO
47. Zhoua N, Cheah CSL (2016) Ecological risk model of childhood obesity in Chinese immigrant children. HHS Public Access 176(3):139–148. https://doi.org/10.1016/j.appet.2015.02.028



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